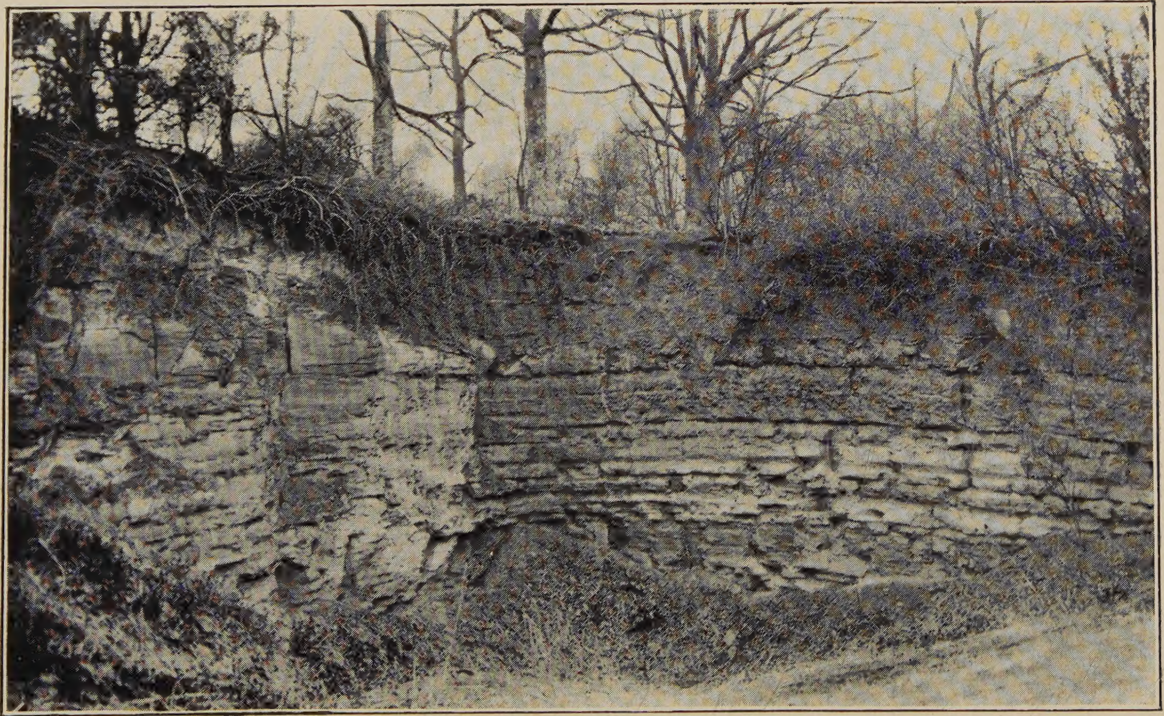
A HANDBOOK

TO THE

GEOLOGY OF CHELTENHAM

AND NEIGHBOURHOOD.



QUARRY AT SARN HILL, NEAR TEWKESBURY.

(From a photograph by G. Railton.)

A Handbook

TO THE

GEOLOGY OF CHELTENHAM

And Neighbourhood.

By

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PREFACE.

The main object of this work is to locate and to describe briefly the various sections in the neighbourhood of Cheltenham. A twofold purpose will, it is hoped, also be gained—(1) to assist the student commencing investigation of the Jurassic rocks; and (2) to help the geologist engaged in original research. Therefore a somewhat unusual plan of arrangement has been adopted. For the former worker an introductory chapter has been written; for the latter, both in that chapter and indeed throughout the book, particular stress has been laid on the employment of technical terms; while special care has been taken to describe accurately the positions of the quarries. The term "hemera" has been adopted as indicative of the time during which a zone of deposit was laid down. Research may show that in a deposit once considered to belong to a single zone are fossils which characterize definite portions of that zone. When such a deposit is investigated over a wide area these fossils may be found to occur in sequence. Accordingly, when such is the case, and when the results of work and the views of another geologist can be more exactly expressed by so doing, it is, in the writer's opinion, desirable that the original zone should be separated into two or more zones. Then each of the new zones would be said to have accumulated during the time-of-existence (or "hemera") of the one or more characteristic fossils. The well-known stratigraphical terms are retained, and their chronological equivalents will be found in the several tables.

The chapter dealing with Denudation, River-development, and Scenery, stands last because it appears imperative that a thorough knowledge should be obtained of the geotectony of a district before the results of denudation can be in any sense adequately appreciated.

With regard to the map which accompanies this work, it is desirable to explain that although the writer

has been engaged in investigating the geology of this district for some time past, he paid no particular attention to the exact limits of the several formations with a view to definite mapping. Consequently, in many places the map does not differ from that published by the Geological Survey, and he is indebted to the Controller of His Majesty's Stationery Office for permission to transcribe any geological information which was required. In some parts, however, the present map does differ, and the reasons for these alterations are recorded in the section (page 263) dealing with the map.

The first work dealing exclusively with the geology of the district was by Sir Roderick Murchison on "An Outline of the Geology of Cheltenham," published in 1834. A second and much enlarged edition of this work was brought out by H. E. Strickland and James Buckman in Cheltenham in 1844, and in the following year in London. In 1857 was published "The Geology of the Country around Cheltenham," by Prof. Edward Hull, being a work descriptive of Sheet 44 of the Geological Survey. Of late years much useful information is given in Mr. S. S. Buckman's "Cheltenham as a Holiday Resort" (1897); while much technical and special research-work has been published in papers which have appeared in the *Quarterly Journal* of the Geological Society, in the *Proceedings* of the Cotteswold Naturalists' Field Club, and elsewhere. Full references to these papers will be found in the text and footnotes of the present work, serving as a guide to those who desire fuller information on the particular subjects under consideration.

In the preparation of the book the writer has availed himself of much information from the numerous papers mentioned in the text and footnotes, and acknowledges his great indebtedness to their respective authors. To Mr. S. S. Buckman, in particular, he is indebted for many notes and ideas, and for ever-ready assistance. Dr. C. Callaway has kindly read through the MS. of the

first and last chapters; and for assistance in palæontological matters the writer is much indebted to Mr. S. S Buckman, Mr. W. H. Hudleston, Mr. W. D. Lang, Mr. E. T. Newton, Mr. A. C. Seward, Mr. R. F. Tomes, and Mr. Charles Upton. To the Councils of the Geological Society, and the Cotteswold Naturalists' Field Club, and to the respective authors, the writer is indebted for permission to reproduce certain illustrations published by those Societies; and Dr. H. Woodward has also kindly given permission to reproduce three figures which appeared in the *Geological Magazine*. Mr. E. B. Wethered very kindly made new negatives of two of these figures.

For photographs of certain quarries the writer owes his thanks to Prof. S. H. Reynolds, and Messrs. J. W. Gray, G. Railton, and F. L. Roberts. To Mr. J. W. Tutcher special thanks are due for his great labour in photographing the fossils depicted in the plates at the end of the present volume; while to Miss A. F. Parkinson the writer acknowledges his indebtedness for the photograph of a portion of her model of the district now in the Ladies' College Museum.

L. RICHARDSON.

Cheltenham,

June, 1904.

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ILLUSTRATIVE FIGURES

BESIDES THOSE IN THE PLATES.

ERRATA.

PAGE 64 Table iii.; *for* Stratagraphical *read* Stratigraphical.

,, 131 Line 17 from top; *for* [*Clypeus Ptoti*] *read* [*Clypeus Ploti*].

,, 181 Note to fig. 12; *for* 1ft. = 4 miles, *read* 1in. = 4 miles.

Table I.—Table of Geological Formations.

Group.	(*Era.*)		System.	Series.
Quaternary.		Anthropozoic.	Post-Tertiary or Quarternary.	Recent and Pre-historic.
				Pleistocene.
Tertiary.	Neozoic.	Kainozoic.	Tertiary.	Pleiocene.
				Meiocene (absent from England).
				Oligocene.
				Eocene.
Secondary.		Mesozoic.	Cretaceous.	Chalk and Gault.
				Neocomian and Wealden.
			Jurassic.	Upper Oolites.
				Middle Oolites.
				Lower Oolites.
				Lias.
				Rhætic.
			Triassic.	Keuper.
				Muschelkalk (absent from England).
				Bunter.
Primary.	Palaeozoic.	Deuterozoic.	Permian.	Magnesian Limestone.
				Permian Sandstone.
			Carboniferous.	Coal Measures.
				Millstone Grit.
				Mountain Limestone.
			Devonian.	Upper Devonian.
				Middle Devonian.
				Lower Devonian.
		Protozoic.	Silurian.	Ludlow.
				Wenlock.
				Llandovery.
			Ordovician.	Caradoc or Bala.
				Llandeilo.
				Arenig.
			Cambrian.	Tremadoc
				Lingula Flags.
				Menevian.
				Harlech.
Archæan.	Azoic		Pre-Cambrian.	Longmyndian.
	Eozoic			Uriconian or Pebidian.
				Malvernian.

Chapter I.

INTRODUCTION.

In its widest sense Geology (from two Greek words —*ge*, the earth, and *logos*, a discourse or reasoning) is the History of the Earth. It deals with the nature and origin of the rocks* which constitute the solid ground on which we live, and with the organic remains embedded in those rocks. It enquires into the physiographic conditions under which the various forms of life existed, and their bearing upon the life, climate, and scenery of the present. This history is admittedly imperfect, but sufficient is known to demonstrate that the earth has undergone great changes during the geologic past, and that many a varied fauna and flora has existed.

The entire series of geological deposits—from the study of which these conclusions are deducible—has been divided into five main groups, the Archæan (Gr. *archaios*, ancient), Primary, Secondary, Tertiary, and Quaternary (*vide* Table I.). The organisms found in the first of these are few and difficult to determine, the greater mass of rock being of igneous origin, but the term sometimes applied to the *era*, "Eozoic" (Gr. *eos*, dawn), indicates the dawn of life. Although we believe on theoretical grounds that the seas of the Eozoic Era were teeming with living creatures, still, as Dr. C. Callaway, F.G.S., has pointed out,† it is only in the newest series of the Archæan Group, known in England as the Longmyndian (after the Longmynd Hills in Western Shropshire), that actual evidence of the existence of life in Pre-Cambrian

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* All masses of mineral matter which actually form part of the earth's crust are known to the geologist as *rocks*.

† "Proc. Cotteswold Nat. F.C.," Vol. XIII., Part II. (1899), pp. 73-83.

times has been obtained. In the Primary rocks the life-forms are totally distinct from those of the present day: in other words the collective fauna is of an ancient type, and the fact is expressed in the name given to the era, Palæozoic (Gr. *palaios*, ancient; *zoe*, life). The term "Mesozoic" (Gr. *mesos*, middle) is self-explanatory, denoting as it does that the life-types are of a character more or less intermediate between those of the Palæozoic Era and those of the Kainozoic (Gr. *kainos*, recent): in the latter of which lived shell-fish and plants now largely prevalent in tropical regions. The chronological term, "Anthropozoic" (Gr. *anthropos*, man), applied to the present era records the existence of man, who became dominant in the Pleistocene (Gr. *pleistos*, most; *kainos*, recent) Epoch.

Some authors, viewing the grander mass of rock and the distinctiveness of the collective fauna of the Palæozoic Era, rightly regard this Primary Group of rocks as considerably more important than those deposited during the Mesozoic and Kainozoic Eras. Accordingly, they consider the Secondary and Tertiary rocks to have accumulated during a single era—that known as the Neozoic (Gr. *neos*, new). Others would divide the Primary Group into two parts, embracing the Cambrian (ancient name of Western Wales), Ordovician (Ordovices, the ancient inhabitants of North Wales), and Silurian (Silures, ancient race of South Wales) Systems, under the term "Protozoic" or "Proterozoic" (Gr. *protos*, first); and the Devonian (after the county of Devon), Carboniferous (Lat. *carbo*, coal; *fero*, I bear), and Permian (after Perm, in Russia) Systems under "Deuterozoic" or "Deutozoic" (Gr. *deuteros*, second).

During the lapse of an era the physical geography underwent several changes, the deposits accumulated in the intervals between the physiographic changes being classed together as a *system*, and the time during which the component deposits were laid down is spoken of as a *period*. Thus the Secondary Group of rocks, deposited during the Mesozoic Era, is divisible into three systems, formed in three separate periods.

Stratigraphically, a system will admit of further division into *series:* for example, the Triassic System is divisible into the Bunter, Muschelkalk, and Keuper Series, and each of these was deposited during an *epoch*. Again, each series includes a number of *stages*, the rocks composing these having been formed during *ages:* and finally, these stages themselves may be regarded as divisible into *zones*—each zone being marked by the presence of some peculiar fossil, or assemblage of fossils, occurring only in that deposit. The time during which the sediment containing the particular zonal fossils was deposited is called a *hemera*; and one notable species in each zone gives its name to the *hemera*.

As Mr. H. B. Woodward has observed in his standard work on the *Geology of England and Wales*, the classification and nomenclature of the stratified rocks is one on which very little agreement is found amongst geologists. Table I. will elucidate the above remarks referring to the stratigraphy; whilst the following will perhaps make the use of the chronological terms plainer.

Stratigraphical Terms.	*Corresponding Chronological Terms.*
1. Group.	1. Era.
2. System.	2. Period.
3. Series.	3. Epoch.
4. Stage.	4. Age.
5. Zone.	5. Hemera.

In Table I. the names of the rocks—with the exception of those denoting the eras, which are chronological terms—are called stratigraphical terms. When the deposits come to be traced over a considerable area they are found to vary considerably in lithic structure and thickness, and of this fact there are numerous illustrations even in so restricted an area as that to be described in the present work, as will be shortly demonstrated. On the one hand the same lithic conditions may hide very different faunas; and unless the faunas be studied the similarity of conditions may lead to false assumptions of contemporaneity.

In the correlation of certain sandy beds known in the several localities as the Cotteswold, Midford, and Yeovil Sands, by the old school of geologists, we have an example of the errors which may be incurred by placing too much reliance upon lithic structure.

As has been repeatedly urged by many Continental and English Geologists, the best guides to life-zones in the Jurassic rocks are ammonites. These fossils appear to have been less influenced by physical conditions than those belonging to other classes, and are, accordingly, more reliable indicators of time. Their ultimate extinction was probably due to the fact that they became so highly specialized that it was no longer possible for them to adapt themselves to the still further changing physical conditions. Another great point in favour of accepting ammonites as indicators of life-zones is that the chronological terms, derived from the names of the ammonites characteristic of the various zones, are of universal application. The new school of geologists, in particular, gives names to the time during which the beds were deposited, and such names are known as chronological terms.

Of late years, what is usually known as the Inferior Oolite has received much attention at the hands of Mr. S.S. Buckman, F.G.S., who strongly advocates the use of such chronological terms, and has written a paper, which was published in the *Quarterly Journal* of the Geological Society of London.

Making use of certain subdivisions very similar to those proposed by Renevier—which are both chronographic and stratigraphic—he suggests the use of hemeral (Gr. *hemera*, a day) names, which may be described as terms indicative of the time during which the sediment—in which is found the zonal ammonite or other fossil—was deposited. Mr. Buckman defines a hemera as "the time during which a particular species—generally in Mesozoic chronology, of an ammonite—has dominant existence."* He has also observed that "while there

* "Quart. Journ. Geol. Soc.," Vol. LIV. (1898), pp. 442-462.

were the stratigraphical terms 'zone,' 'stage,' and the chronological term 'age' for the time of a 'stage,' there was no chronological term to denote the time of a 'zone.' So 'hemera' was proposed to supply the deficiency. 'Hemera,' 'age,' are the time terms; 'zone,' 'stage,' denote the amount of work done in the way of deposition during these times; they are the stratigraphical terms."

"A hemera marks the acme of development of one or more species, as a chronological term. Just as a 'day' marks the phenomenon, sunrise, high noon, sunset, or, if one likes to put it so, from sunrise to sunrise again, so a 'hemera' was designed to mark the time from species-rise to species-rise—that is, from the time when one species or set of species becomes dominant to the time when another species or set of species does so. Such time intervals were to be termed 'hemeræ.' And so many 'hemeræ' make an 'age,' just as so many 'days' make a 'week.'"* Mr. W. H. Hudleston, F.R.S., has remarked, "When all demurrers have been duly considered, there remains a considerable balance in support of the chronological value of Ammonite zones." In the Ordovician rocks the chronological term to denote the time of a zone may be based upon the dominant existence of a particular species of graptolite, and in the Chalk of a *Micraster*, or some other echinoid or fossil.

In every district it is possible to investigate some rocks, and to assist in perfecting, as far as possible, the History of the Earth. True, some localities offer more opportunities for investigating the rocks composing them than others, and around Cheltenham we are fortunate in having an exceptional development of the Inferior Oolite. In the area under consideration—the western half of Sheet 44 of the Geological Survey Map—the deposits from the Upper Keuper to the Forest Marble inclusive may be examined.

The student, however, who makes Cheltenham his centre need not restrict his attention to these rocks.

* "Geol. Mag.," Dec. IV., Vol. IX. (1902), p. 555.

Should he desire to become acquainted with the rocks below the Keuper, he will find the lower portion of the series—consisting chiefly of red and white sandstones—in the neighbourhood of Newent or at Huntley; whilst the Bunter Sandstone occurs around Bromesberrow. At Haffield and Hayes Copse the Bunter Sandstone is in contact with breccias, which have been referred to the Permian System. A breccia is a coarse rock composed of angular fragments of stone which have been broken off some rock and cemented together by a paste of fine mud or sand, by a deposit of carbonate of lime, or by some other chemical substance. In the Forest of Dean are the Carboniferous rocks. Here the strata form a very perfect "basin": on the outside are the encircling rings of Mountain Limestone and Millstone Grit, whilst in the centre are the Coal Measures. At May Hill a knowledge of the Silurian System may be obtained. The central mass is formed of May Hill Sandstone or Upper Llandovery; then comes the Woolhope Limestone, followed in ascending order by the Wenlock Shales, Wenlock Limestone, and the Ludlow Series, whilst to the west succeeds the Old Red Sandstone. The Hollybush Sandstone and Malvern Black Shales, belonging to the Cambrian System, occur to the west of the southern end of the Malvern Hills.

The Malverns themselves are composed of Archæan rocks of two ages: the older being known as the Malvernian, and the newer as the Uriconian—the latter visible at Tinker's Hill, the eastern spur of the Herefordshire Beacon;* while the still later series of the Archæan, the Longmyndian, may be studied in the quarry about a quarter-of-a-mile west of Huntley Church.† The Uriconian is named after the "Wrekin," which had previously given a similar name to the Roman city of Uriconium, which lay under the shadow of the hill. The results of dynamo-metamorphism are well

* "Quart. Journ. Geol. Soc.," Vol. XXXVI. (1880), pp. 536-539.

† *Ibid.*, Vol. LVI. (1900), pp. 518-520.

exemplified in the Malvern Hills. Dynamo-metamorphism may be defined as the alteration of rocks by lateral pressure or crust-creep, which more or less obliterates the original structural characters of the rocks affected, and causes to be developed an entirely new set of structural features. Dr. C. Callaway has pointed out in the *Quarterly Journal* of the Geological Society,‡ in the *Proceedings* of the Cotteswold Club,§ and elsewhere,|| that the Malvern crystallines were once an igneous complex,—that is to say, they were a mass of igneous rocks, chiefly a granite (the well-known Malvern red granite is what is known as a binary granite, on account of its constituents being only two in number, namely, quartz and felspar), and two or three varieties of diorite, which were intruded into each other in veins, dykes, and masses. After these rocks had consolidated, they were subjected to enormous pressures, which caused them to give way in places and to shear and slide, thereby eventually simulating sedimentary deposits: in fact, the old school of geologists looked upon the Malvern crystallines as altered sedimentary rocks. This crushing and shearing naturally generated much heat, and great chemical changes resulted.

If a knowledge of the Upper Jurassic and Cretaceous (Lat. *creta*, chalk) rocks be desired, excursions of under thirty miles in a south-easterly direction will place the student upon them. The rocks described in the following pages belong to the Secondary Group, and are all aqueous or sedimentary—that is, they have all been deposited by water. Since they have a prevalent dip to the south-east, it follows that by traversing this district in that direction newer rocks will be successively entered upon. The

‡ *Ibid.* Vol. XLIX. (1893), pp. 398-425; *ibid.* Vol. XLV. (1889), pp. 475-503; *ibid.*, Vol. XLIII. (1887), pp. 525-536.

§ "Proc. Cotteswold Nat. F.C.," Vol. XII., Part III. (1898) pp. 239-247.

|| "Proc. Liverpool Geol. Soc.," 1895-96, p. 453.

oldest must, therefore, be sought for in the north-west, and such belong to the Triassic System.

The section (fig. 1) from Coomb Hill to Leckhampton Hill will illustrate how the rocks lie in this neighbourhood,* and shows the sequence of deposits from the Upper Keuper Marls to the Great Oolite. The thicknesses of the several stages are as given by Professor Edward Hull, F.R.S.

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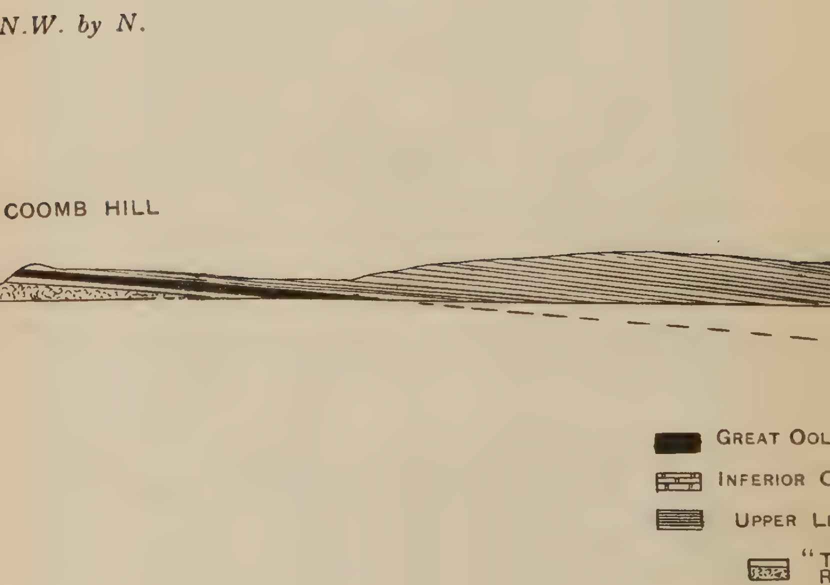
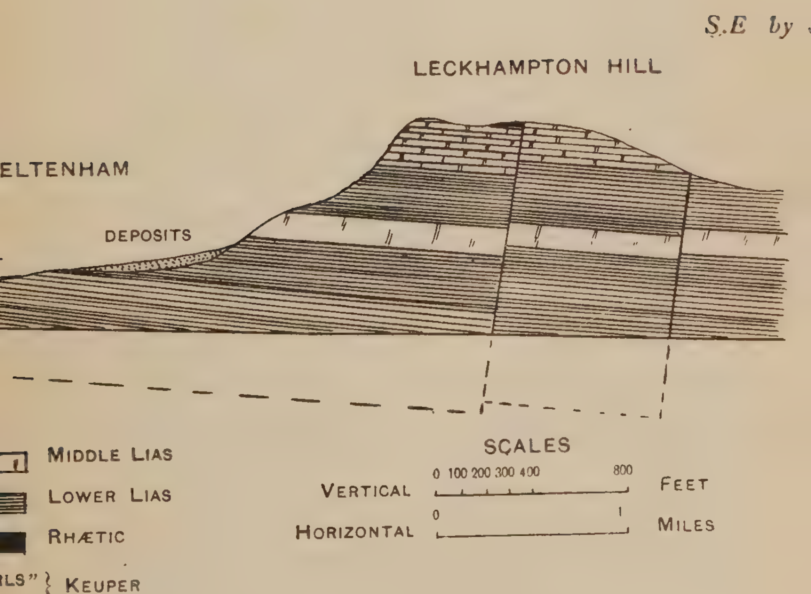
*The faults are as shown on the Geological Survey Map.

SECTION FROM COOMB

FIG. 1.



LL TO LECKHAMPTON.



Chapter II.

THE TRIASSIC SYSTEM.

The oldest system of the Secondary Group is the Triassic. As the name given to it by H. G. Bronn implies, where typically developed it can be separated into three series, and as these are most markedly developed in Germany, German names have been applied to them. The names of the three series in descending order are the Keuper, Muschelkalk, and Bunter. Some authors would include the Rhætic Series in the Triassic System, giving as a reason that the included fish-remains have more palæontological affinity with those of the Trias than with those of the Lias ; but, on the other hand, we have in the Rhætic the remains of those huge reptiles, the *Ichthyosaurus* and *Plesiosaurus*, which became so numerous in early Liassic times. Although certain of the Lamellibranchiata—the class to which the common cockle and such like shell-fish belong—are very characteristic of the Rhætic, on the whole that class of fossils serves to link these rocks with the Lower Lias, from which, however, they are distinguished in Britain by the absence of Cephalopoda—no species of ammonites or belemnites having yet been found in the true Rhætic of this country.

The Bunter Sandstone may be examined in the neighbourhood of Bromesberrow, and consists of coarse-grained sandstones, of various colours. The Muschelkalk—a marine deposit full of shells—has not been identified in England, and, consequently, we have only the upper and lower series of the Triassic System represented.

THE UPPER KEUPER.

The name Keuper, applied to the newest series, is a provincial German term, and is pronounced *Koyper.*

The Keuper Series is divided into two stages, an upper and a lower. The Lower Keuper, or *Waterstones*, comprises red and white sandstones and marls, and may be examined around Newent. The Upper Keuper deposits are the oldest rocks in the area under consideration, and consist of red and green marls, with occasional sandstones. If an excursion be made to Deerhurst, the red colour of the ground around that interesting village will at once indicate that we are on the Red Keuper Marls. That the redness of the ground where these and similarly coloured rocks prevail attracted the attention of the former inhabitants is shown by the place names, such as Rudford, Redmarley, Redditch, and Radstock.

About 215 feet below the base of the Lower Rhætic—or 250 feet below that of the Lias, the rock which constitutes the subsoil of the greater part of the vale to the east of the Severn—is a deposit of sandstone of variable thickness, but seldom exceeding 20 feet. The nearest locality to Cheltenham where this Upper Keuper Sandstone occurs is at Notcliff,* its presence being proved by the débris in the fields and the rising ground upon which the hamlet is, for the most part, situated. It is visible in the south bank of the cutting through which the road from Notcliff passes, and just before its junction with the Apperley road. In the village of Ripple the same rock is well exposed near the Schools, and once was more deeply sectionized in the railway-cutting a little to the west. It was here that the Rev. W. S. Symonds observed the richest Keuper "bone-breccia" he knew of in England, and some excellent specimens of it may be seen in the Museum of the Victoria Institute at Worcester. There is a good exposure of about 7 feet 2 in., of this sandstone in a disused quarry half-a-mile north-north-west of Naunton, near Hill Croome, the section showing 2 feet 8 inches of calcareous sandstone, 2 feet 6 inches of alternating layers of greenish marl and sandstone, and about 2 feet of more massive sandstone.

* Now often called Deerhurst Walton.

The red marls above the Upper Keuper Sandstone are visible about one-and-a-half miles to the east of Evesham, their western limit being faulted. This fault brings strata of the Lower Lias Stage into juxtaposition with the marls, and although no physical feature reveals the line of junction, the change of colour from the greyish soil of the Lias to the red of the Keuper is most marked. Standing at some point on the line where this phenomenon is observable—say, about a mile to the east of Bricklehampton—and looking up to the superior height of Hasler Hill (which is capped about a hundred yards from the western escarpment by the basement beds of the Lower Lias), some estimate may be formed of the "throw" (or amount of vertical displacement) of the fault which has brought Liassic strata—higher in the series than those capping Hasler Hill—into juxtaposition with the Keuper Marls: probably it exceeds 260 feet.

To the west of the area under review the Keuper Sandstone is well exposed in the neighbourhood of Eldersfield, and formerly was extensively quarried near Pendock Church, but this latter section is now quite overgrown. Many plant- and vertebrate-remains, together with the horny protective coverings or carapaces of the little crustacean *Estheria minuta*—a form still existing, and delighting in brackish water, and whose two shells so much resemble those of a bivalve that they were once considered to belong to the Lamellibranchiata, and denominated *Posidonomya minuta*—have been obtained. A piece of Keuper Sandstone, from Birtsmorton, containing plant-remains, is exhibited in the Worcester Museum.

Above the Upper Keuper Sandstone is a deposit attaining a thickness of about 215 feet, and consisting essentially of a variegated, bluish-green and red marl, the red colour preponderating. The upper twenty feet or so are of a greenish tint, and are called by the Government Geological Survey the "Tea-Green Marls," and classed by them with the Rhætic. The reason given for this classification is that on the map it has been found

most practicable to draw the boundary between the Keuper and Rhætic at the base of these marls.*

If, however, a casual observer was asked where the Keuper deposits ended and the Rhætic began, he would doubtless place his finger on the sharp line of junction where these "Tea-Green Marls" are opposed in strong contrast to the black shales of the Rhætic.

The two best sections for studying the upper portion of the Upper Keuper deposits are at the Mythe Tute and Wainlode Cliff; but there are numerous exposures in shallow road-cuttings in the neighbourhood of Deerhurst and Forthampton; in the cuttings on the Malvern, Tewkesbury, and Ashchurch line between Ripple and the Mythe Tute; and in the road-cutting at Tunnel Hill, where there is exposed one of the greenish-grey arenaceous bands so common in this portion of the series.

The "Tea-Green Marls" are well exposed at Wainlode Cliff, and in a road-cutting a little to the north of Norton Church; but they may be also seen in a field-track a little to the south-west of "The Folly," Deerhurst; in the cutting through which the Ledbury and Tewkesbury road passes at Bushley; in an old excavation a little to the west of Manor Farm at Hill Croome; three-quarters-of-a-mile east of Netherton, near Evesham; and at Coomb Hill—the nearest loality to Cheltenham where the Keuper beds are visible.

If the distribution of the green-coloured marl in the cliff at Wainlode be closely studied, two points will at once force themselves upon the mind of the observer. The first is the apparent adventitious occurrence of the green blotches, and the second is that such green patches seem related to the stratification. That the arrangement of the red and green colours in the Keuper Marls is very capricious and anomalous has been remarked by George Maw, who further observed "that any satisfactory explanation is rendered difficult, on the one hand, by the

* But *vide* "Mem. Geol. Surv., 'The Geology of the South Wales Coal-field,' Part III., 'The Geology of the Country around Cardiff'" (1902), p. 38.

THE MYTHE TUTE,
TEWKESBURY.

(From a photograph by G. Railton.)

disposition of colour being evidently related to the stratification, and on the other by its being evidently the result of secondary causes."* Several theories have been advanced in explanation of these various tints of green and grey: that held by the late Edward Wilson was that probably the green marls were once red in colour and non-calcareous, and have since become bleached and calcareous in part by the downward infiltration into them of some deoxidizing chemical agent and carbonate of lime, derived from the decomposition of the abundant organic remains in the overlying Rhætic shales.†

Gypsum, which occurs so abundantly at some localities, as at Aust Cliff, near Bristol, is found very sparingly in this district. Further north, at Droitwich, the marls contain many layers of rock-salt. According to H. E. Strickland, a strong brine spring was found on Defford Common by sinking through the Lias into the upper portion of the marls.‡

The general absence of fossils, and the usual occurrence of gypsum and rock-salt, leads one to enquire under what conditions the Keuper beds were accumulated. A geographical restoration of this neighbourhood in late Keuper times shows an inland sea to have extended all over this area as far as the Malvern Hills, which most probably formed part of the coast-line. The evidence afforded by the deposits themselves would point to a state of conditions analogous to those connected with the Caspian of the present day, or with the lake in Ethiopia known as the Bahr Assal. This lake once formed part of a gulf of the Red Sea, but is now separated from it by a barrier of lava. Exposed to the fierce rays of an African sun, this salt lake—not fed by any fresh-water rivers—has been reduced to "an elliptical basin, seven

* "Quart. Journ. Geol. Soc.," Vol. XXIV. (1868), pp. 387-394.

† *Ibid.*, Vol. XLVII. (1891), p. 548; *ibid.*, Vol. XXXVIII. (1882), p. 451.

‡ "Memoirs of H. E. Strickland," by Sir W. Jardine (1858), p. 160.

miles across, half-filled with smooth water of the deepest blue, and half with a solid sheet of glittering snow-white salt, the offspring of evaporation."* Although fed by several rivers, the influx of water into the Caspian Sea is less than that evaporated, and the result is that there are extensive low-lying areas surrounding this sea, the level of which is over eighty feet below that of the Black Sea.

The level of the water in the Upper Keuper sea had probably been similarly reduced previous to the deposition of the Upper Keuper Sandstone. Such evaporation would give rise to clouds, rain would fall, and the ordinary processes of detrition would be set in motion. Sand derived from the Old Red Sandstone district to the west would be washed down, and would fill up the cracks in the marl: cracks which would arise from the drying of the marl as the waters of the inland sea retreated. The freshened state of the water would be more favourable to the existence of life—a thesis supported by the "bone-breccia" at Ripple and other localities. After this temporary pluvial period, which must have considerably augmented the waters of the Keuper sea, there was a recurrence to former conditions, and about 215 feet of marl was deposited. Then, as Sir Andrew Ramsay and Mr. A. J. Jukes-Browne have demonstrated, just before the epoch during which the English Rhætic Series was deposited, the Keuper sea was again greatly reduced by evaporation, perhaps several hundred feet below that of the ocean outside. It has been already pointed out that the level of the Caspian is over eighty feet below that of the Black Sea, so that if the waters of the latter were admitted to the former through the depression of the present barriers, they would quickly spread over a large area in Central Asia which is now, for the most part, a dry and sandy district; and a similar drama would be enacted in the neighbourhood of the Bahr Assal were the barrier of lava by some cause removed. Such an invasion seems to have occurred at the close of the Keuper

* Major Harris, "The Highlands of Ethiopia."

Epoch, when the Rhætic ocean gained access to the British inland sea, or what remained of it.

THE CHELTENHAM MINERAL WATERS.

A description of the Upper Keuper deposits of this district would scarcely be complete without some reference to the Cheltenham Mineral Waters. These saline springs find their way to the surface on the principle of artesian wells, except in certain cases, as at Pittville where borings have been made. "From the analyses of these waters by several distinguished chemists, it appears that their principal constituents are the chloride of sodium (muriate of sodium), or sea salt, and the sulphates of soda and magnesia. Sulphate of lime, oxide of iron, and chloride of magnesia, are present in some wells only, and in much smaller quantities."* In a booklet published by the Cheltenham Corporation are analyses of the waters made by Prof. Thorpe in 1893. The source of the saline ingredients of these waters is, doubtless, the Upper Keuper Marls. The dip of these deposits, as we have already seen (fig. 1), is usually to the south-east, and as their outcrop area is at a greater elevation than Cheltenham, it follows that water falling upon the marl would percolate along the beds in the direction of the dip, and endeavour to rise wherever it could find a fissure. In passing upwards, however, the saline water comes in contact with strata full of iron-pyrites, and it is to be presumed that during this upward passage certain chemical changes take place, which give to the waters their most valuable medicinal qualities. The most important chemical process would be "the decomposition of the sulphuret of iron, which supplies a large quantity of the sulphate of the oxide of iron, a process which must be highly accelerated by the structure of these incoherent and finely laminated beds, through which the pyrites is so very widely disseminated.

* Murchison's "Geology of Cheltenham," new ed. by H. E. Strickland and James Buckman (1844), p. 65.

The sulphuric acid thus generated will necessarily re-act on the different bases, such as magnesia and lime, which it may meet with in the strata, and form those sulphates so prevalent in the higher or pyritous beds of the Lias, the oxide of iron being at the same time more or less completely separated. By such means, it is presumed that these mineral waters, which are principally brine springs of the greatest depths, acquire additional and valuable properties in their rise. In suggesting this explanation we must not, however, overlook the fact that fresh water is perpetually falling from the atmosphere upon the surface of the Lias clay, more or less percolating its uppermost strata. Many of the saline springs must therefore be somewhat affected by this cause." In 1839 Sir Roderick Murchison wrote: "At the new Spa near Tewkesbury, the water, though very slightly saline near the surface, was found to be much more impregnated with salt as the sinking was carried downwards, and I have no doubt that similar results would follow by deepening any of the mineral sources which are so numerous in the vale of Gloucester, those of Walton, the bottom of Churchdown Hill, etc., for instance."

Chapter III.

THE JURASSIC SYSTEM.

On account of the magnificent development of the strata composing this system in the Jura Alps, on the borders of France and Switzerland, the term "Jura Limestone" was first suggested by Von Humbolt. This term he employed as early as 1795, but only in a very limited geological sense. In 1823 he used the more comprehensive names, "Jurassique" and "Jura formation," but it was not until some time after Dr. A. Oppel's "Juraformation" was published that the term Jurassic was generally adopted in this country. To English Geologists in particular this system is classic from the fact that William Smith, "The Father of English Geology," distinguished and arranged in their natural order of sequence its component series, and established the important principle that strata can be identified by their organic remains.

The superficial extent of the Jurassic rocks in England is very considerable, extending from the shores of the English Channel between Swanage and Lyme Regis, through the Midland Counties, to the coast of the German Ocean between Flamborough Head and the Tees; whilst outlying masses occur in the counties of Somerset, Glamorgan, Monmouth, Worcester, Shropshire, and Cumberland. In this range, however, the Jurassic rocks vary considerably in lithic structure and thickness. Even in the Cheltenham district there are numerous examples of such phenomena, but in spite of these the fossils are well marked, so that although no general characteristics derived from the texture of the beds composing the system can be given, their correlation is not so difficult a matter as might be at first supposed. Authorities differ

as regards the classification of the Jurassic strata, but that adopted for the present purpose is as follows :—

Jurassic.	Upper	Purbeck Beds.	Upper.	Oolite.
		Portland Beds.		
		Kimmeridge Clay.		
		Corallian Beds.	Middle.	
		Oxford Clay.		
	Middle.	Great Oolite Series.	Lower.	
		Inferior Oolite Series		
	Lower.	Lias.		
		Rhætic.		

THE RHÆTIC.

At the summit of the Alpine Trias is a thick series of fossiliferous strata, which has been called by Dr. C. W. Gümbel the Rhætic Series, on account of its fine development in the old Roman province of Rhætia, where it attains a thickness of 1,400 to 2,000 feet. In England, however,the thickness of the series rarely exceeds 35 feet, but it is improbable that the one is the contemporaneous representative of the whole of the other : most probably Rhætic conditions had obtained in the typical locality, whilst the late Keuper deposits were accumulating in the British area. There is not much difficulty in seeing where the Rhætic Series commences in this district : the line of junction is clearly defined, palæontologically and lithologically. This, however, is not the case as regards the upward extension of the series, which has always been a subject of much debate.

The term, "*Avicula contorta* zone," was suggested for the Rhætic beds by Dr. T. Wright, of Cheltenham, in the year 1860 ; whilst, in 1864, Sir Roderick Murchison proposed the name of "Penarth Beds." The Rhætic Series has been divided into two stages—an upper and a lower, the latter based upon the distribution of that very distinctive lamellibranch, *Avicula contorta*.

At the base of the Lower Lias in Somerset there is present a variable set of beds, consisting of white

and cream-coloured limestones and shales, commonly spoken of as the "White Lias." As Edward Wilson, however, rightly observed, this quarryman's term is a most unfortunate one, for ever since it was adopted by William Smith, in the year 1815, it has been applied by various authors to very different strata. The writer has employed the term "*pre-planorbis*" for those beds occurring between the strata known to yield the ammonite, *Psiloceras planorbis*—or shown by the other organic contents to be of this latter date—and the Upper Rhætic, and characterized by the apparent absence of ammonites and by the abundance of *Modiola minima* and *Ostrea liassica*.

There is a peculiar interest attached to the study of the Rhætic rocks in this district, from the fact that it was probably at Wainlode and Coomb Hill that H. E. Strickland first recognised the importance of the beds, and described them, in 1842, under the name of the "Bristol Bone-bed," or the "Lias Bone-bed." The junction of the Rhætic and Keuper Series is marked by a low but very distinct escarpment, which in this district has, approximately, a north and south trend. There are several "outliers"—or exposed patches of newer rock surrounded on all sides by strata of greater antiquity—of the Rhætic rocks, capped by the basement beds of the Lower Lias. The chief Rhætic section in this district is at Wainlode Cliff, near Gloucester (*vide* Plate III.).*

SECTION AT WAINLODE CLIFF.

	Ft.	Ins.
Lower Lias (*pre-planorbis*)—		
Limestone, hard, blue; *Modiola minima*, *Ostrea liassica*	0	4
Shales, brown and grey; *Pseudomonotis decussata*	1	3†

* "Proc. Cotteswold Nat. F.C.," Vol. XIV., Part II. (1903), table facing p. 174, pp. 128-140; "Memoirs of H. E. Strickland," by Sir W. Jardine (1858), p. 156; "Quart. Journ. Geol. Soc.," Vol. XVI. (1860), p. 379; "Monogr. Foss. Estheriae," Pal. Soc. (1862), pp. 67, 68.

† Transition-bed.

		Ft.	Ins.
Upper Rhætic.	1. Limestone, *Pseudomonotis*-bed. Hard dark-blue and grey; insect-remains	0	5
	2. Shales, blue and brown, marly	5	2
	3. Limestone, *Estheria*-bed; *Naiadita lanceolata*, *Estheria minuta* var. *Brodieana*, fish-scales	0	6
	4. Shales, greyish-yellow; *Schizodus Ewaldi*, *Modiola minima*, *Cardium cloacinum*	6	0
Lower Rhætic.	5. (*a*) Shales, black. Full of fossils	3	0
	5. (*b*) Limestone, very hard; *Pecten valoniensis*	0	1
	6. Shales, black	0	10
	7. Limestone, blue, pyritic; *Pecten valoniensis*, *Saurichthys acuminatus*, *Gyrolepis Alberti*, *Pleurophorus*, *Schizodus*, *Avicula contorta*........	0	3
	8. (*a*) Shales, black, thinly laminated; *Avicula contorta*, *Protocardium rhæticum*	4	6
	8. (*b*) Shales, black, non-laminated	0	10
	9. Sandstone, intermittent band......	0	0–1
	10. Shales, black	0	6
	11. Sandstone, very pyritic	0	1
	12. Shales, black, firm; *Protocardium rhæticum*, *Avicula contorta*, *Modiola minima*, *Gervillia præcursor*	1	1
	13. Sandstone, two layers separated by clay parting	0	2½
	14. Shales, black, clayey..............	1	0
	15. Sandstone, (BONE-BED); *Hybodus minor*, *Gyrolepis Alberti*, *Saurichthys acuminatus*, *Modiola* cf. *minima*, coprolites, etc.	0	3
	16. Shales, black, firm................	2	0
Upper Keuper—	I. "Tea-green Marls"	23	0
	II. Red Marls ......about	75	0

WAINLODE CLIFF, NEAR GLOUCESTER.

(From a photograph

Doubtless, when examining the Upper Keuper Marls in this section, attention was attracted by the remarkable series of black shales which immediately succeed. These black shales belong to the Lower Rhætic Stage. At that end of the cliff furthest from the Red Lion Hotel the junction of the "Tea-green Marls" and Rhætic black shales is (1903) well exposed in an excavation made for collecting water. Two feet above these "Tea-green Marls" is a remarkable stratum containing fish-remains in great abundance. This bed is known as the Bone-bed, and comprises several thin sandstone layers, separated by black clayey partings, but it is the lowest and thickest layer which is the most ossiferous. The collective thickness does not exceed three inches here. Few rocks are prettier than the lowest layer of the Bone-bed at this locality when washed free of its covering of black shale, the yellow iron-pyrites and black vertebrate-remains standing out in pleasing contrast. If the bed be carefully split along the planes of stratification, some excellent specimens of fish-scales and teeth will be obtained. The scales of a fish called *Gyrolepis* are the most abundant of the vertebrate-remains, the teeth including *Acrodus minimus*, *Saurichthys acuminatus*, and one very much resembling the fine portion of a needle, and presumably belonging to some actinopterygian fish—possibly *Gyrolepis*. At Aust Cliff, near Bristol, the Bone-bed has yielded in great abundance the tooth of another fish, known as *Ceratodus*. The Rev. W. S. Symonds observed that they had been found at Wainlode Cliff, and also at Garden Cliff, near Newnham, but whilst we know that they should occur in the Bone-bed at these localities, still it is desirable that the records should be confirmed. It is interesting to note that this type of fish is preserved in the mud-fish of the rivers of Queensland, and one of the recent fish from the Mary River is to be seen in the Bristol Museum, close to a fine series of the fossil teeth from the Aust Bone-bed. As a thin pyritic stratum crowded with vertebrate-remains, however, this Bone-bed is not always to be recognised. If it

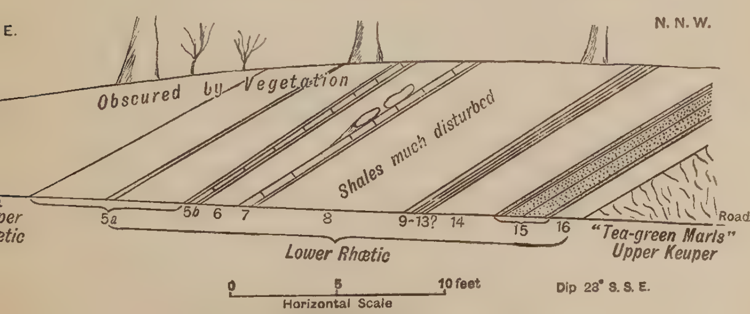
be traced a few yards to the right of the above-mentioned exposure at Wainlode Cliff, it will be seen to pass, by almost imperceptible gradations, into a greenish-yellow micaceous sandstone, the vertebrate-remains being very sparingly distributed. In the left bank of the road descending to the Red Lion Hotel it is represented by a brown micaceous sandstone, about a foot thick, and containing in some abundance Strickland's "*Pullastra arenicola*." Since this fossil usually occurs as ill-defined casts, it is difficult to say to what genus it really belongs—some authors consider it to be a species of *Schizodus*.

Above the Bone-bed are black shales, with inter-stratified sandstone and limestone bands, collectively attaining a thickness of 12 feet 4 inches, and replete with fossils at certain horizons. In the sandstone bed, which occurs a foot above the Bone-bed, the writer has detected the comparatively rare mineral, Baryto-Celestine—an amorphous combination of the sulphates of both minerals. The most prolific deposit as regards lamellibranchs succeeds, and is one foot thick. Throughout this thickness the shales are crowded with *Protocardium rhæticum*, *Schizodus Ewaldi*, and *Modiola minima*, the tests being usually replaced by iron-pyrites. At 8 feet 2 inches above the Bone-bed is the Lower *Pecten*-bed, so called on account of its yielding in considerable numbers *Pecten valoniensis*—a shell much resembling a small scallop. This stratum is, practically, made up of the crushed tests of lamellibranchs, though well-preserved specimens may be occasionally obtained. Moreover, it is in places of the nature of a "bone-bed," and the same remark applies to the hard limestone band, which occurs ten inches above again. The succeeding deposit of black shales which completes the Lower Rhætic Stage is highly fossiliferous, but, as at other localities, and at the same horizon, they are much crushed. The Upper Rhætic Stage commences with a deposit of greenish-yellow marly shales, but their position in the cliff will not allow of a very detailed examination. If a typical set of the Rhætic lamellibranchs be desired, the equivalent

deposit at Garden Cliff is much more accessible. The *Estheria*-bed is the next deposit in ascending order, and consists of a limestone presenting variable lithic structure. The main lithic varieties are four in number, and in the district between Sedbury Cliff, near Chepstow, and Bourne Bank, near Defford, they are remarkably persistent. One variety simulates the markings observable in the Cotham Marble of the Bristol district. Fish-scales and plant-remains (*Naiadita lanceolata*) occur in association with the carapaces of *Estheria minuta* var. *Brodieana*, but these fossils are by no means abundant at Wainlode. The *Pseudomonotis*-bed is the same as the Rev. P. B. Brodie's "Insect-limestone," the former term having been adopted in preference to the latter on account of the indiscriminate use to which the term "Insect-limestone" has been put: in one place being applied to a stratum clearly of Rhætic Age, and in another to strata of the hemera *planorbis*. It was at Wainlode Cliff that the insect-remains were first observed by Mr. Brodie, and subsequently that author extended his researches, and embodied the results in his classic work on "A History of the Fossil Insects in the Secondary Rocks of Britain," published in 1845. A quarry on the Gray Hill, Apperley, yielded to that enthusiastic worker many excellent insect-remains, but now the section is quite overgrown.

In the lane-cutting which breaches the escarpment some three hundred yards north-east of Norton Church, the Lower Rhætic Stage is exposed (fig. 2), but the

Fig. 2.—Section at Norton, near Gloucester.



component deposits are much compressed and disturbed, having an unusual dip of 28° S.S.E. The following section is transcribed from my paper on "The Rhætic Rocks of North-west Gloucestershire."*—

SECTION AT NORTON, NEAR GLOUCESTER.

	Ft	Ins.
4. Shales, greenish-yellow, marly, coarsely laminated.		
5*a*. Shales, black, coarsely laminated, with brownish partings, sandy layers near base. These shales are equally divided by a sandstone-band, containing *Schizodus Ewaldi*, *S. elongatus?* *S. concentricus*, and *Avicula contorta*	1	9
5*b*. Limestone, hard, grey; above and below are veins of fibrous Calcite; Selenite; *Pecten valoniensis*, *Myophoria*, scales of *Gyrolepis*	0	2
6. Shales, brownish-black	0	4
7. Limestone, dark greenish-brown, in nodular masses, containing *Modiola minima*, and *Avicula contorta*, resting upon bluish-black limestone, containing *Pecten valoniensis*, *Schizodus*, *Avicula contorta*, *Gyrolepis Alberti*, and much shell débris......	0	4–8
8*a*. Shales, brownish-black, finely laminated, firm; *Schizodus*	3	0
b. Shales, brownish-black, coarsely laminated	1	4
9 to 13? Series of sandstone bands, with clay partings................	1	1
14. Shales, black, imperfectly laminated, selenitic; somewhat arenaceous at 5″ above the Bone-bed............	1	9

* "Proc. Cotteswold Nat. F.C.", Vol. XIV., Part II. (1903), p. 141.

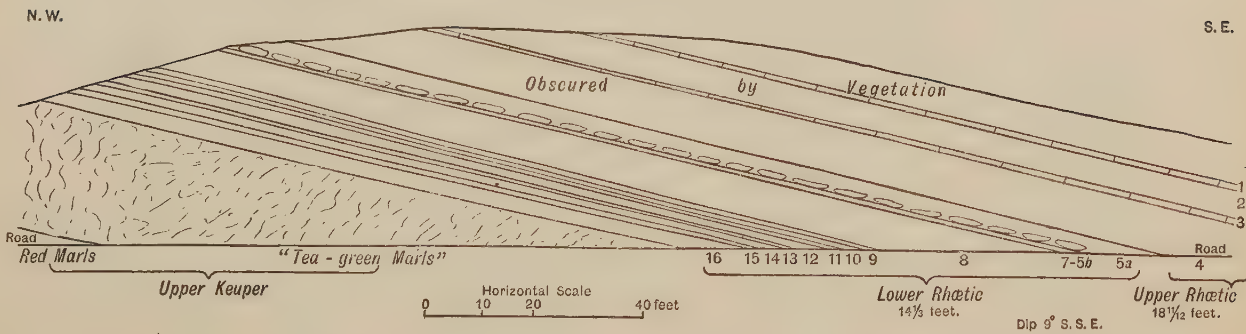
	Ft.	Inn.
15. Sandstone, (BONE-BED); very hard, light-grey, calcareous; *Gyrolepis Alberti*, *Saurichthys acuminatus*....	1	3
16. Shales, blackish-grey	1	4

Upper Keuper—I. Very light greenish-grey marl.
II. Red Marls.

The thickness of the Bone-bed is noteworthy: it weathers into seven main layers, the fourth from the base being the most fossiliferous. The next important section is at Coomb Hill, near Cheltenham (fig. 3), in the sides of the cutting through which the road to the disused canal passes. The section afforded is very similar to that at Wainlode Cliff. The Bone-bed—which is not always very easy to find—is in places richly fossiliferous, the matrix being very pyritic. A little excavating of what may appear to be a rain-water course down the north bank soon reveals the sequence of deposits. About 1 foot 8 inches above the Bone-bed the shales are crowded with lamellibranchs, and another fossiliferous horizon occurs 7 feet 5 inches above the Bone-bed, or 1 foot 5 inches below the Lower *Pecten*-bed. This latter bed has yielded some very well-preserved fossils, including a very fine *Pleurophorus*, together with *Pecten valoniensis*, *Schizodus Ewaldi*, *Modiola minima*, and *Avicula contorta*. The Upper Rhætic beds are, unfortunately, obscured by vegetation, but pieces of the *Estheria*- and *Pseudomonotis*-beds are procurable. The former bed, lithically, resembles that at Wainlode, and has yielded the writer specimens of *Estheria* and *Naiadita*. The *Pseudomonotis*-bed is a light-grey fissile limestone, portions of which may be found at the top of the south bank of the cutting at the Coomb-Hill end. Insect-remains are more abundant here than at Wainlode, and in addition to these small specimens of *Modiola minima* are of frequent occurrence.

To the south-east of Deerhurst the basement beds of the Rhætic, with the subjacent "Tea-green Marls," are exposed in a deeply-cut wheel-track. A sandstone

Fig. 3.—SECTION AT COOMB HILL, NEAR CHELTENHAM.



[*Vertical scale somewhat exaggerated.*]

Recent work in Worcestershire shows that beds Nos. 5B and 6 are frequently absent, and such is the case at Coomb Hill. Consequently, in this figure, and in that given on page 146 of my paper in "Proc. Cotteswold Nat. F. C.," Vol. XIV., the beds numbered 5B—7 should read bed 7.

[*Figs. 2 and 3 reproduced by permission of the Cotteswold Naturalists' Field Club.*]

band, the equivalent of that a foot above the Bone-bed at Wainlode, contained a specimen of the coral *Heterastræa*: an exceedingly interesting "find," since it is the only authentic record of a coral from the English Lower Rhætic.*

Near Bushley, the Tewkesbury and Ledbury road passes through a shallow cutting, the exact position of the section being a little over half-a-mile to the north-east of Forthampton. That section which can be made out in the road-cutting at the present time (1903) is as follows :—†

SECTION IN ROAD-CUTTING NEAR BUSHLEY.

		Ft.	Ins.
Lower Rhaetic.	Shales, black, laminated		
	13. Sandstone, micaceous, pyritic, non-calcareous	0	4
	14. Shales, black, imperfectly laminated	1	1
	15. Sandstone (BONE-BED-EQUIVALENT); micaceous, soft; scales of *Gyrolepis*, "*Pullastra*," *Modiola* (the broad form), *Avicula contorta*....	1	2
	16. Shales, black, firm, imperfectly laminated	2	8
Upper Keuper.	I. Greenish Marls; "Tea-green Marls"	20	0
	II. Red Marls.		

The only bed well exposed, however, is the Bone-bed-equivalent. About a mile to the south-south-west of Upton-on-Severn is an outlier of Rhætic strata capped by beds of *pre-planorbis* and *Psiloceras planorbis* date, but sections in the first-named rocks are wanting.

Interesting information concerning certain beds may be obtained in and near the road-cutting at Bourne Bank, near Defford. The Bone-bed-equivalent is two feet

*Vide "Quart. Journ. Geol. Soc.," Vol. LIX. (1903), p. 403.

† "Proc. Cotteswold Nat. F.C.," Vol. XIV., Part II. (1903), p. 150; "Geology of the Country around Cheltenham" (1857), p. 14; "Quart. Journ. Geol. Soc.", Vol. XVI. (1860), p. 380.

thick, and lithically is identical with the contemporaneous stratum at Bushley. Fairly-well defined casts of lamellibranchs occur, and the cavities between the casts and surrounding matrix frequently contain small quantities of the mineral Baryto-Celestine. The locality, however, is most notable for the excellent specimens of *Estheria minuta* var. *Brodieana* which occur in the *Estheria*-bed; the bed itself appearing at the surface in the wood to the north of the cutting. The associated plant-remains are equally well preserved. About a mile-and-a-half to the west of Evesham the Rhætic beds are again visible, and the escarpment they form is breached by the Pershore road—the cutting revealing a bed of yellowish-white sandstone (Bone-bed-equivalent) with casts of lamellibranchs.

At the close of Keuper times we saw that the sea of that epoch in the British area had probably been again considerably reduced by evaporation, and that in its shrunk condition it was environed by low-lying areas similar to those surrounding the Caspian and the Bahr Assal of the present day. When the southern Rhætic ocean gained access to the British area it would quickly spread over these low-lying districts of Keuper Marl, and an unconformity between the deposits of the two series would result. True, it is difficult to appreciate this unconformity from occular demonstration, for this reason, that it is impossible to say how much of the Keuper deposit is wanting, as there are no horizons of organic remains to guide us. At the present time it is only possible to interpret the probable sequence of physiographic events in late Keuper and early Rhætic times by comparing the deductions which may be derived from a consideration of the facts available with analogous present day phenomena. To take an example: if the waters of the Black Sea were admitted into the Caspian, there, where the shrunk sea still existed and deposition was going on, the sequence would be complete from the accumulations formed previous to the ingression to those deposits formed under the new conditions, but where the

waters spread over the surrounding low-lying areas there would be an unconformity, or, more correctly speaking, a non-sequence.*

With the inroad of the Rhætic ocean came the marine reptiles, the *Ichthyosaurus* and *Plesiosaurus*. In the Bristol Museum there is a specimen of the former "Sea-Lizard," twenty-two feet in length. The fish included *Acrodus*, *Saurichthys*, and *Gyrolepis*, all of which flourished extremely, as is evidenced by the Bone-bed at Aust, Sedbury, Penarth, Garden, and Wainlode Cliffs. That the beds of the Lower Rhætic Stage accumulated under marine conditions is clearly shown by the occurrence of star-fish ; but it is improbable that the arm of the Rhætic sea extending over the British area anywhere attained more than a very moderate depth, and the most ossiferous development of the Bone-bed seems to usually occur near the ancient coast-lines. The mode of occurrence of the upper deposits of the Lower Rhætic Stage suggests slight changes in the level of the sea-floor—changes which must have produced conditions suitable for the existence of the brackish-water-loving crustacean *Estheria minuta* var. *Brodieana*. At the time of the deposition of the *Pseudomonotis*-bed, or "Insect-limestone," the sea appears to have become somewhat deeper. A remarkable fact discovered by Mr. Westwood, after an examination of several hundred specimens of insect-remains from this stratum, was that the whole presented indications of a temperate climate—a conclusion, as Strickland noticed, wholly opposed to that which we are accustomed to draw from the vertebrate and molluscan remains of the same epoch. The difficulty, however, is soon removed. Sir Andrew Ramsay stated that, in his opinion, the mountains of Wales were probably then at least double their present height, so that, even if a warm temperate fauna existed along

* This term is preferable to "unconformity," since the latter is applicable to a marked discordance, whereas in order to discover a non-sequence it is necessary to trace the strata over a considerable area before the discordance becomes apparent.

the coast, a cold land fauna might exist among the hills. This opinion is supported by the fact that whilst dredging along the coast of Lycia, Professor Forbes noticed that during the rainy season the surface of the waters was often partially covered with quantities of dead insects, washed into the sea from the neighbouring land. By far the greater number of the insects were not derived from the hot low-coast territories, but were borne to the sea from the more distant and lofty mountain lands.* "There are, probably, no organic bodies of such delicate structures which are capable of floating to so great distances as insects; their extreme lightness and the strong materials of which their corneous parts consist, would enable them to float down rivers and to be diffused far and wide over the sea, there to be embedded with truly marine products." Thus, whilst the Keuper Epoch closed with a scene of arid wastes, and an inland sea reduced to slowly-shrinking lakes, the Liassic Epoch dawned with a sea full of active creatures, bordered by a fertile region, "where the splash of waters and the hum of insects were unceasing sounds."

* "Memoirs of the Geological Survey," Vol. I. (1846), p. 325.

TABLE II.—THE LIASSIC SERIES.

[*To face page 35.*

	Geological Survey.		Approximate Zonal Terms used by Wright and Witchell.	Chronological Terms (mainly following S. S. Buckman). Hemera.	Age.	Epoch.	Renevier's Chron'graphic Subdivisions.
Inferior Oolite Series.	Inferior Oolite.	Cephalopoda-bed.	*opalinum*-zone.	*opaliniformis.*	Harpoceratan.	Arietidan.	Toarcian.
				aalensis.			
				Moorei.			
Liassic Series.	Midford Sands and Upper Lias. (Midford Sands = Cotteswold Sands)		*jurense*-zone.	*Dumortieriæ.*			
				dispansi.			
				striatuli.			
			Cotteswold Sands.	*variabilis.*			
				Lilli.			
		Upper Lias.	*bifrons.*	*bifrontis.*			
			serpentinum.	*falciferi.*			
				acuti.			
	Middle Lias.	Middle Lias.	*spinatum.*	*spinati.*	Deroceratan.		Pliensbachian.
			margaritatus.	*margaritati.*			
				algoviani.			
				capricornu.			
			Henleyi.	*striati.*			
			ibex.	*Valdani.*			
			Jamesoni.	*Jamesoni*			
				petti.			
				armati.			
	Lower Lias.	Lower Lias.	*raricostatum.*	*raricostati.*			
			oxynotum.	*oxynoti.*	Asteroceratan.		Sinémurian.
			obtusum.	*stellaris.*			
				obtusi.			
			Turneri.	*Turneri.*			
			Bucklandi.	*Birchi.*			
				gmuendensis.			
				rotiformis.			
			angulata.	*marmoreæ.*	Calo-ceratan.		Hettan-gian.
				megastomatos.			
			planorbis.	*planorbis.*			
				pre-planorbis.			
Rhaetic.							Rhaetian (as division of

Chapter IV.

THE LIAS.

GENERAL DESCRIPTION.

Above the Rhætic comes the familiar series of clays and limestones, the former predominating, known as the Lias. Anyone who has noticed the deep excavations in the roads or streets of Cheltenham will have observed that they reveal a bluish clay, perhaps capped by a little sand or gravel, or the last two combined. This clay belongs to the Liassic Series. The term Lias, or "Lyas," as it was then spelt, was employed in a geological sense as early as 1719. It is thought to be a corruption of the word "layers"—the term applied by the Somerset quarrymen to the thin argillaceous limestone beds which occur towards the base of the Lower Lias, and are especially well marked in that county.

That the Lias early received considerable attention is not to be wondered at, seeing that the organic remains are rich and varied, and, on the whole, well-preserved. The Lias has been divided into three stages, an upper, middle, and lower; and these have been subdivided into zones, each characterized by a certain ammonite. Particular zones thus characterized constitute each of the three divisions, but as to where the line should be drawn between the middle and lower stages, authorities are not in complete agreement. Thus, whilst the Geological Survey consider the zones of *Amaltheus margaritatus* and *Paltopleuroceras spinatum* to compose this middle division, most Foreign and English Geologists throw the junction-line considerably lower down, regarding it as coming between the zones of *Echioceras raricostatum* and *Uptonia Jamesoni*. Mr. Buckman would

draw the line between the *varicostatum-* and *oxynotum-*zones. Of late years Mr. S. S. Buckman has recognised some additional zones. Table II. shows the Geological Survey classification ; that adopted by Witchell ; chronological terms mainly following Mr. S. S. Buckman's arrangement ; and Renevier's chronographic subdivisions. I have recognised most of the deposits of the hemerae recorded by Mr. Buckman, but my list differs slightly from his.

THE LOWER LIAS.

It has been already stated that below the beds known to belong to the *planorbis*-zone, are certain deposits which have been dated as *pre-planorbis* and, provisionally, these beds are grouped with the Lower Lias. To quote Dr. T. Wright, " the neighbourhood of Tewkesbury affords several good sections of these infra-ammonite beds " (*i.e.*, the *Ostrea-* and Saurian-beds = *pre-planorbis*-beds). At Keynsham the equivalent beds have been denominated the " sub-ammonite beds," and grouped with the Lower Lias.*

At Coomb Hill the section must have been very instructive in the days of Murchison,† showing, as it did, the sequence of deposits from the *planorbis*-beds to the Upper Keuper Marls. " In descending order we first perceive about 12 thin courses of dark-coloured calcareous flagstones, which are extracted for roads, paving, building, and burning to lime. These courses vary in thickness from 1 to 3 inches, and are separated from each other by stiff marl : the two lowermost bands, known locally as the ' Rattler ' and the ' Bottom bed,' are alone burnt for lime."

" The surface of the flagstones is frequently covered with numerous fine and delicate species of Echini ; and bones and vertebræ of Saurian animals have also been found. These beds are underlaid by sandy pyritiferous

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* " Proc. Bristol Nat. Soc.," Vol. X, Part I. (1901), p. 13.

† " The Silurian System " (1839), p. 20.

shale, graduating downwards into cream-coloured marl, succeeded by shivery, finely laminated, black shale, highly charged with iron pyrites and small crystals of selenite, and containing a few thin courses of whitish sandstone."

Although most of the quarries are abandoned, several sections are obtainable, namely, at Sarn Hill, Heath Hill, and near Hill Croome Church. That at Sarn Hill is reached by getting over the stile on the north side of the main-road cutting at Bushley—the cutting in which the Rhætic beds are exposed. This quarry, now becoming overgrown, shows the beds to comprise alternating deposits of clay and limestone, weathering grey and brown.

QUARRY AT SARN HILL, NEAR TEWKESBURY.

	Ft.	Ins.
Subsoil, with a few quartzite pebbles........		
1. Marl	2	0
2. Limestone, bluish-grey, earthy, weathers into two layers	0	3
3. Shales, calcareous, grey and brown, laminated below first ten inches	3	0
4. Limestone, bluish-grey; *Ostrea liassica*, *Lima* cf. *gigantea* (small), *Pecten*	0	3
5. Shales, grey, weather brown; fish-scales, *Ostrea liassica*	1	1
6. Limestone, grey, earthy	0	3
7. Shales, grey, weather brown	0	2
8. Limestone, bluish-black; *Ostrea liassica*	0	3
9. Shales, arenaceous limestone layers near the base; *Ostrea liassica*............	0	10
10. Limestone, hard, bluish-black; *Ostrea liassica*	0	9
11. Shales, parting	0	1
12. Limestone, hard, buish-black	0	4
13. Shales, grey and brown, *Modiola minima*	0	3
14. Limestone, hard, bluish-black..........	0	4
15. Shales		

Certain of the *pre-planorbis*-beds, and, in particular, a thin limestone band, are crowded with the spines and portions of the tests of a small sea-urchin, but the writer has not detected this limestone band *in situ* here, although pieces on the spoil-heap attest its presence. A bed containing such remains, but a little lower down in the series, is seen in the quarry near the cottages on the Heath-Hill outlier to the south of Upton-on-Severn, where the "bottom-bed" has also been reached; and again two-and-a-quarter miles south-west of Evesham, where the echinoid remains are most abundant. A shallow quarry, excavated in beds not far removed from the base of the Lias, about five hundred yards north-east of Hill Croome Church, affords the following section:—

QUARRY NEAR HILL CROOME CHURCH.

	Ft.	Ins.
Subsoil, reddish; about	2	0
1. Shales, calcareous, grey and brown, the uppermost twenty inches imperfectly laminated. Fragments of the spines and tests of sea-urchins	4	3
2. Limestone, bluish-grey, earthy, full of shell fragments; *Pecten*, *Protocardium*, *Pleuromya crowcombeia*	0	2½
3. Shales, calcareous, grey and brown, visible	1	0

(1) *Zone of Psiloceras planorbis.* Where the beds of this zone *are* exposed, the characteristic ammonite is most abundant, and especially in the shaly deposits. Strata of this date occur at Wainlode Cliff, and from the fallen blocks of limestone on the river-bank may be hammered out, besides the zonal ammonite, *Ostrea liassica*, *Modiola minima*, *Pinna*, *Pleuromya*, and *Lima gigantea* (small). They have been quarried at Sarn Hill, a little to the north of the quarry in which the *pre-planorbis*-beds are exposed. The ammonite occurs abundantly, but much crushed—otherwise fossils are rare (Plate I.).

QUARRY AT SARN HILL, NEAR TEWKESBURY.

	Ft.	Ins.
1. Shales, grey, calcareous, weather brown; visible	6	0
2. Limestone, brown, argillaceous	0	1½
3. Shales, grey, weather brown; *Psiloceras planorbis*	1	11
4. Limestone, grey, earthy; spines of sea-urchins	0	4
5. Shales, grey, weather brown; *Psiloceras planorbis*	1	5
6. Limestone, hard, grey	0	5
7. Shales; *Psil. planorbis: Ostrea*, and several other lamellibranchs	1	8
8. Limestone, hard, grey	0	3
9. Shales, bluish-grey, weather brown; *Protocardium* cf. *rhæticum*	2	7
10. Limestone, hard, grey	0	3
11. Shales, bluish-grey, weather brown		

At the southern end of the Heath-Hill outlier is the best exposure of the beds under consideration.

QUARRY AT HEATH HILL, NEAR UPTON-ON-SEVERN.

1. Shales, grey, weather brown; *Gervillia, Ostrea liassica*; visible	4	6
2. Limestone, brown, argillaceous	0	1½
3. Shales, grey, weather brown; *Psiloceras planorbis, Ostrea liassica*	2	9
4. Limestone, hard, bluish-grey; *Psil. planorbis*	0	4
5. Shales, light-brown and grey; *Psil. planorbis, Modiola minima, Pecten*, fish-scale. The ammonites occur the most abundantly at nine inches below the superincumbent limestone	1	11
6 Limestone, hard, grey, an occasional *Ostrea* on the upper surface; *Rhynchonella* cf. *calcicosta*, Quenstedt	0	5

	Ft.	Ins.
7. Shales, grey; *Psil. planorbis, Ostrea liassica, Macrodon*	1	11
8. Limestone, grey, earthy; shell fragments....	0	3
9. Shales, grey; visible..................	2	0

A comparison of the above section with that at Sarn Hill shows them to be very similar. Of this outlier, or the Longdon-Heath outlier as it was called, Sir Roderick Murchison wrote that six beds were quarried on it, and that they were known by the names of "Top," "Black," "Tile," "Poacher," "Peaver," and "Bottom." "The Poacher is an irregular course, appearing and disappearing; the 'Bottom' is the best stone, and is seven inches thick. The strata on the north-west end of the hill dip east-south-east 6°, but where they crop out the inclination increases to 12° and 15°. On the higher parts of the hill the dip is north-east, and in its east-north-eastern face there are quarries twenty feet deep, where the dip is west-south-west. This outlier, and the range of Lias by Bushley, are, for the most part, covered with drifted superficial matter, composed of red clay, or gravel and sand, which generally conceals the subsoil in this part of Worcestershire."* At Brockeridge Common the same strata were once largely worked, but now the quarries are quite overgrown.† "As the Lower Lias occupies the highest ground in the environs of Tewkesbury, it is there dignified by the title of the 'hill rock,' in contradistinction to the red marl, which is usually in the lower ground."‡

(2) *Zone of Schlotheimia angulata.* Beds usually referred to this zone have been found to have accumulated during two hemeræ—the hemeræ *megastomatos* and *marmoreæ.* Deposits of the former date are not

* "The Silurian System" (1839), p. 21.

† *Ibid*, p. 21; "A History of the Fossil Insects in the Secondary Rocks of England" (1845), p. 67 *et seq.*; "Monograph of the Lias Ammonites of the British Isles," Pal. Soc. (1878), p. 18.

‡ "The Silurian System" (1839), p. 21.

exposed in this district ; but those of the latter, according to Mr. S. S. Buckman, have been worked in a now disused quarry near the Lower Reddings Farm, Churchdown. The most interesting fossil here is a *Rhynchonella*, called *Rhyn. calcicosta* by Davidson, which may be found lying about on the spoil-heap in a loose state. The details now (1903) obtainable are as follows :—

Section near the Lower Reddings Farm, Churchdown.

	Ft.	Ins.
1. Marl, blue and yellow	2	0
2. Limestone, hard, bluish-grey ; ossicles of *Pentacrinus*, *Gryphæa arcuata* (or *incurva*), *Rhynchonella calcicosta*, Dav.	0	7
3. Marl, blue and yellow		
4. Limestone, hard, bluish-grey ; *Rhynchonella calcicosta*, Dav.	0	6
5. Marl, blue and yellow ; visible	0	4

The same beds are exposed in the banks of the stream a little to the south-west. Mr. Edward T. Paris conducted me to a slight elevation, known locally as Peas Hill, about half-a-mile north of The Reddings, where the ploughed fields are covered with fragments of *Gryphæa arcuata*. Mr. H. B. Woodward was informed by Mr. T. J. Slatter that the *angulata*-zone was exposed in the cuttings of the Midland Railway between Evesham and Bengeworth Stations. *Cardinia ovalis* was abundant in places ; and *Cardinia hybrida* has been found at Bengeworth.

(3) *Zone of Coroniceras Bucklandi.* The beds commonly distinguished as the *Bucklandi*-beds have been found to have accumulated during three hemeræ, those of *rotiforme*, *gmuendense*, and *Birchi*. Beds of the hemera *rotiformis*, together with deposits of later date, are dug for brick-making at Bengeworth, near Evesham, the most fossiliferous deposits occurring at the bottom of the pit. The clay at this and other pits in the Lower Lias is usually dug the most extensively during the

winter months, consequently, for fossil-collecting, it is best to visit them during that period. Unfortunately, in the level surface of the vale, pits are gradually becoming fewer in number. This, I am informed, is due to agricultural depression, the influence exerted being that in many cases the farmers are unable to meet the expenses incurred by using tiles for draining purposes, and so have had to resort to open ditches. Moreover, it will have been noticed that the greater number of the quarries in the basement limestones of the Lower Lias are abandoned, and this is due to the fact that railways, and the greater facilities now afforded for the distribution of road-metal and building-stone, have obviated the necessity for working the local rock.

The fossils at Bengeworth include *Gryphæa arcuata* (large and very abundant), *Cardinia hybrida* (abundant), *Ostrea liassica*, Ammonites (*Arnioceras* and *Coroniceras*), *Montlivaltia Haimei*, *Lucina limbata* and *Unicardium;* whilst Mr. H. B. Woodward also collected *Pleurotomaria anglica*, *Avicula inæquivalvis*, *Schlotheimia Charmassei*, and *Arnioceras semicostatum*.

In the left bank of the brook (the southermost, or what is known as the Ham Brook) between the Churchdown and Badgeworth roads, Mr. Edward T. Paris showed me an exposure of stiff blue clays with a limestone band. This limestone bed yields *Aviculæ* and small *Limæ:* also a *Rhynchonella* of a form very closely allied to, if not the same as, that so abundant at Hock Crib, Fretherne. According to Mr. Buckman, the upper beds at Fretherne are of the hemera *gmuendensis*.

(4) *Zone of Aretites Turneri*. Deposits of this date were said to be sectionized in the Coldpool cutting near The Reddings; and again on the same line at Bredon, for Strickland has recorded the zonal ammonite, and also ammonites indicative of beds laid down during the hemeræ *Birchi* and *obtusi*. It must be remembered, however, that no ammonite has been more miscalled than *Arietites Turneri*.

(5) *Zone of Asteroceras obtusum.* "The beds constituting this zone," wrote Dr. Wright, "are well developed in the vale of Gloucester, and were exposed in cutting the Bristol and Birmingham Railway near Bredon, from whence the best collection of the fossils from this zone in the Midland Counties was obtained. The rocks consist of dark-grey and bluish shales and clays, with irregular and inconstant beds of dark-grey argillaceous limestone . . . . ." In addition to the exposure in the railway-cutting at Bredon, Mr. H. B. Woodward has noted the occurrence of the *obtusum*-beds on the west bank of the River Isbourne, near Toddington.

(6) *Zone of Oxynotoceras oxynotum.* These beds, which consist of dark clays, often containing much ferrous sulphide and ferrous oxide, have been opened out in railway and drain excavations at Lansdown, Cheltenham, where a number of fossils have been obtained; and recently (1902) in drain excavations at Overbury, on the southern slope of Bredon Hill, where a magnificent example of *Oxynotoceras oxynotum* was found. The fossils found in these clays are usually very pyritic. The same beds were formerly dug on the east bank of the Avon, near Great Comberton, and contain (1902) *Belemnites* sp., *Gryphæa*, and a *Cardinia;* and in an earthy limestone, crushed specimens of a *Rhynchonella*.

(7) *Zone of Echioceras raricostatum.* Deposits of the hemeræ *raricostati* and *armati* are dug for brick-making at the Folly-Lane Pit, to the north-west of the town; and consist of dark-coloured clays. The earlier beds are excavated in the lower portion of the pit, those laid down during the later hemera in the upper. The ammonite *Microceras subplanicosta* is abundant. The other fossils include that now rare lamellibranch, *Hippopodium ponderosum;* and *Cardinia Listeri*, *Gryphæa arcuata*, *Belemnites* cf. *breviformis*, *Belemnites oxyconus*, *Dentalium limatulum*, and *Turritella*. The gasteropods and scaphopods—chiefly of the genera *Turritella* and *Dentalium*—may be found by searching the clay-flats below the northern bank of the disused portion

of the pit. According to Dr. Wright, the *raricostatum*-beds were formerly worked at Cleeve. Prof. Ralph Tate has given lists of fossils obtained by him from the *oxynotum*- and *raricostatum*-zones chiefly in the neighbourhood of Cheltenham, and figures several new species from the district under consideration.* He also states his opinion that the line of demarcation between the lower and middle stages of the Lias should be drawn between the *obtusum*- and *oxynotum*-zones.†

(8) *Zone of Uptonia Jamesoni.* "Upwards of twenty years ago," wrote Dr. Wright, in 1879, "I collected several fragments of the whorls of a large *Ægoceras Jamesoni* in some deep brick-pits near Leckhampton, which was the first evidence we had that this zone existed near Cheltenham." I am unable, however, to to confirm this statement.

(9) *Zones of Acanthopleuroceras Valdani and Liparoceras striatum.* The Lias exposed in the pits in the more immediate neighbourhood of the town has always been well known amongst geologists as richly fossiliferous. According to the classification adopted by most authors it belongs to the Middle Lias, having been deposited during the hemeræ *Valdani* and *striati*; but, as already stated, the Geological Survey do not consider the middle division to embrace deposits lower down than the somewhat arenaceous shaly beds which come just below the "rock-bed" of the Middle Lias.

There are four clay-pits which may be described as situated to the east of Cheltenham, namely, at Shackel's Pike, at the foot of the picturesque Battledown Hill, at Pilford (or, as it is usually called, Pilley), and at Leckhampton Station. For convenience of descriptive purposes we may here consider together the *Valdani*- and *striatum*-zones.

The pit at Shackel's Pike, on the Cemetery Road, is not very satisfactory from a fossil-collector's standpoint.

* "Quart. Journ. Geol. Soc.," Vol. XXVI. (1870), p. 397.
† *Ibid*, p. 400.

Fragments of the zonal ammonites, however, may be found, and show during what hemeræ the beds were deposited, whilst along the clay-bank facing a little to the north of west numerous ossicles of Pentacrinus may be picked up—fossils which "look like little stars." Occasionally *Belemnites* spp. and small gasteropods may be procured.

The pit belonging to Messrs. Webb Bros., and situated at the foot of Battledown Hill, has been excavated in beds of about the same date, but here we have numerous layers of argillaceous and ferruginous nodules embedded in the clay, which could not be seen *in situ* at Shackel's Pike, although there were indications of them in the highest of the now-abandoned workings. The inference is that the clay now worked at Shackel's Pike is on the same horizon as that excavated near the bottom of Messrs. Webb's pit. These nodules, which the workmen collect for mending the roads in the brick-yard, are replete with fossils, including *Cardinia attenuata*, *Gervillia lævis*, *Liparoceras striatum*, *Rhynchonella fimbria*, Quenstedt, *Zeilleria* cf. *perforata* (*Piette*), *Terebratula subovoides Spiriferina punctata*, *Arca* (*Macrodon*) *Buckmani*, *Arca Stricklandi*, *Inoceramus ventricosus*, *Acanthopleuroceras Valdani*, *Rhacoceras Loscombei*, *Belemnites*, and *Pentracrinus*-ossicles. Several of these fossils will be found figured in the revised edition of Murchison's "Geology of Cheltenham."* In the blue clay fragments of *Liparoceras striatum* and *Acanthopleuroceras Valdani* are common, together with *Inoceramus ventricosus*. At the eastern extremity of the pit portions of crinoid-stems were very numerous.

That the term "Lias" originated in a corruption of "layers" may seem at first questionable from the evidence afforded in these clay-pits, but it must be remembered that the beds here seen constitute the upper

* (Cheltenham, 1844; London, 1845), table 10. A *Liparoceras* from Charlton Kings was figured by Murchison as *Ammonites cheltensis*.

portion of the Lower Lias (*i.e.*, according to the Geological Survey classification), and that it is the strata below the zone of *Microderoceras Birchi*—often referred to as the *semicostatum*-beds—that the layers are so apparent, as anyone who knows the Keynsham and Radstock quarries can testify.

Deposits of the hemera *Valdani* are dug at Leckhampton Station, and besides the zonal ammonite yield a number of other fossils, such as *Cerithium ibex*, *Turbo admirandus*, *Dentalium*, and *Belemnites* spp. At Hucclecote brickyard, about half-a-mile west by south of Brockworth Church, beds on about the same horizon contain a multitude of *Belemnites*: mainly of the species *clavatus* and *longissimus*. The other fossils obtainable are *Inoceramus ventricosus*, *Pecten* cf. *æqualis*, Quenstedt, *Turritella*, and *Cerithium ibex*.

The *striatum*-beds were formerly worked at Greet, near Winchcomb; and near Didcot Farm, north of Alderton Hill, where they were found to consist of blue and brown clays, with many ironstone-nodules, cement-stones of a grey tint, and masses of shelly limestone. A large number of fossils has been obtained, but the pit is now abandoned.*

The pit at Pilford (or Pilley), Leckhampton, on the left-hand side of the Old Bath Road, perhaps repays the fossil-collector as well as any. The beds, comprising blue and brown clays with both ironstone-nodules and argillaceous cement-stones, were deposited at a later date than those already noticed, the prevailing ammonite being of a *capricornu*-type, and usually occurring in the limestone-nodules. Fallen masses of rock contain *Amaltheus margaritatus*—an ammonite indicative of a subdivision of the superincumbent stage, the Middle Lias. The *Liparoceras capricornu* marks a distinct horizon, which occurs just above the *striatum*-beds. Portions of the clay are considerably indurated and arenaceous, and contain many fossils. The limestone-

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* "Proc. Cotteswold Nat. F.C.," Vol. III. (1865), pp. 153 *et seqq.*

nodules, however, yield the best-preserved specimens. The fossils to be procured here include *Avicula inæquivalvis*, *Pecten æquivalvis*, *Nuculana graphica*, *Modiola scalprum*, *Gervillia* cf. *lævis*, *Gryphæa cymbium*, *Pleuromya costata*, *Pholadomya*, *Pinna*, *Arca* (*Macrodon*) *Buckmani*, *Cucullæa*, *Ostrea*, *Astarte obsoleta*, *Cypricardia intermedia*, *Rhynchonella*, and *Liparoceros capricornu*.

The lowest beds dug in the large pit on Robins' Wood Hill yield *Liparoceras capricornu*, in association with many other fossils, similar to those obtainable at Pilford; whilst there are also exposed deposits of later date above (*algoviani ?*). Near the junction of the road from Charlton Kings with that leading through Timbercombe is a small disused pit excavated in a bluish-grey, somewhat shaly deposit, with a line of ferruginous nodules. In these nodules the writer found a few small gasteropods and a *Rhynchonella*. As no distinctive fossils were obtained, it was impossible to fix the exact date of the beds exposed.

Mr. H. B. Woodward says: "at Cranham Pottery about 12 or 15 feet of blue micaceous clay, containing a few ferruginous nodules, has been exposed. There I obtained specimens of *Ammonites striatus* and *A. Jamesoni ?* Flower-pots, pans, drain-pipes, jugs, &c., are manufactured at this pottery, which dates back to the time of Queen Elizabeth, if not earlier."* It will be seen upon referring to the Geological Survey Map that the deposit in which this pit is excavated is represented as being Upper Lias, and in any case it is difficult to understand how *Liparoceras striatum* was recorded.

THE MIDDLE LIAS.

We have now to consider the Middle Lias according to the Geological Survey classification. Along the flanks of the Cotteswolds a flat narrow terrace is nearly everywhere seen, and to the south of the Stroud Valley it is

* "Mem. Geol. Surv. 'The Jurassic Rocks of Britain,'" Vol. III. (1893), "The Lias," p. 143.

considerably more marked. This terrace—especially noticeable about a mile to the south of Upton St. Leonard's—is caused by the presence of the " rock-bed," or Lias Marlstone. Below the Marlstone are arenaceous micaceous shales, considerably indurated in places. This Marlstone comprises the zones of *Amaltheus margaritatus*, and *Paltopleuroceras spinatum*. Dr. Wright has remarked that at Bredon, Alderton, and Stanley Hills " it is difficult to separate the Margaritatus from the Spinatus bed." A portion of the upper part of the subjacent shaly beds belong to the *margaritatus*-zone, so that the lithic characters of the deposit characterized by *Amaltheus margaritatus* may be described as arenaceous shales and sandstones, occasionally calcareous and often ferruginous, the hard beds being blue internally but weather brown. The lithic characters of the beds belonging to the *spinatum*-zone are variable, and may be described either as (1) friable light-brown micaceous sandstone, or (2) a hard ferruginous or calcareous rock in which the fossils are well preserved but difficult to extract.

Taking the outliers first, the position of the " rock-bed " is easily determined on Robins' Wood Hill, constituting as it does, tabulated promontories. On Churchdown or Chosen Hill the rock was once extensively quarried, but now only a very small exposure is available. The beds at this locality have been minutely described by Dr. F. Smithe.* On referring to page 56 of the present work it will be seen that the uppermost beds of the Middle Lias here consist of soft yellow calcareous sandstones—with a line of nodules at the top—containing *Belemnites* spp. and *Plicatula spinosa* in some abundance, and that they pass downwards into a more compact rock yielding many fossils. Battledown Hill, to the east of Cheltenham, may be capped by the Marlstone, but sections are wanting.

There is an indifferent exposure on Oxenton Hill, a little to the south-west of Dixton Wood, and here *Pecten*

* " Proc. Cotteswold Nat. F.C.," Vol. VI. (1876), p. 349; " The Silurian System " (1839), pp. 17, 18.

æquivalvis and a few *Belemnites* spp. have been obtained. From the low-lying ground half-way between the villages of Gretton and Alderton the dip of the Marlstone capping the northern spur of Oxenton can be very easily ascertained, but it should be borne in mind that this somewhat excessive inclination is due to the fault on the south side of the outlier. Dixton Hill, with its tabulated summit, stands out like a huge tumulus: the Marlstone which caps it being very ferruginous and containing numerous *Belemnites* spp.

The beds on Alderton Hill are very fossiliferous, and once were widely known in this respect,* but now an examination of the weathered stones in the walls alone demonstrates the cause of its former reputation. On the weathered stones have (1902) been observed, *Amaltheus margaritatus*, *A. nudus*, *Paltopleuroceras* sp., *Belemnites paxillosus*, *Rhynchonella amalthei*, *Rhyn. acuta*, *Rhyn. tetrahedra*, *Terebratula punctata*, *Aulacothyris resupinata*, *Gryphæa cymbium*, *Pleuromya*, *Modiola*, *Pecten*, &c., all well-preserved.

On the Bredon outlier exposures of the "rock-bed" are numerous, and in a cutting on the road from Elmley Castle up the hill the subjacent brown arenaceous shaly beds are visible, and again above Ashton-under-Hill. Although there are good exposures of the "rock-bed" above the villages of Bredon's Norton and Ashton-under-Hill, the best is situated a little to the east of the road ascending the hill from Woollas Hall, and is as follows:—

QUARRY ON THE NORTH FACE OF BREDON HILL.

	Ft.	Ins.
1. Brown and grey, flaggy, somewhat arenaceous limestone; *Rhynchonella*, *Belemnites* spp.	2	10
2. Soft sandy bed	0	5

* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,' Vol. III. (1893), 'The Lias,'" p. 216; "Proc. Cotteswold Nat. F.C." Vol. III. (1865), pp. 153, 154; *Ibid.*, Vol. X. (1892), p. 207; Murchison's "Geology of Cheltenham" (1844), p. 38.

	Ft.	Ins.
3. Hard, brown, and grey, flaggy limestone ; *Paltopleuroceras spinatum*, *Belemnites*, *Pecten æquivalvis*, *Rhynchonella tetrahedra*	2	9
4. Soft sandy bed, with a few *Belemnites*....	0	10
5. Hard, brown, and grey limestone ; *Amaltheus margaritatus*, *Rhynchonella* cf. *amalthei*, *Aulacothyris florella*, *Pecten*, etc. ; visible	1	2

The sections above Ashton-under-Hill have been described by Mr. H. B. Woodward,* but the beds are not nearly so fossiliferous as those exhibited in the section given above.

QUARRY ABOVE ASHTON-UNDER-HILL.

	Ft.	Ins.
Soil, brown, fragments of rock	2	0
1. Pale grey, flaggy, arenaceous limestones ; *Belemnites*, *Pleuromya*, *Rhynchonella tetrahedra*, *Pecten*	2	0
2. Rubbly bed of arenaceous limestone ; *Belemnites* spp.	1	4
3. Grey and brown limestone ; *Pecten æquivalis*	2	6

South of Gretton, near Winchcomb, the Marlstone was once extensively worked, and many organic remains obtained, but the quarries are now abandoned.†

Following the escarpment of the Cotteswolds in a north-easterly direction from Haresfield Beacon we find the "rock-bed" of the Middle Lias exposed in the deep road-cutting at Prinknash, and the colour of the spring water close at hand indicates the extremely ferruginous nature of the rock off which the water flows. At the present time there are few exposures of the component

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* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. III. (1893), p. 217.

† "Proc. Cotteswold Nat. F.C.," Vol. X. (1892), p. 209; "Mem. Geol. Surv. 'Geology of the Country around Cheltenham'" (1857), p. 23.

deposits of the Middle Lias Stage in the immediate vicinity of Cheltenham : there is a small one of the Marlstone in a lane at Charlton Kings (just above the *a* in Ham on the Geological Survey Map) which is richly fossiliferous—the fossils including *Belemnites paxillosus*, *Rhynchonella tetrahedra*, *Pinna*, *Pecten*, and *Modiola*. Below are micaceous shales, much indurated in places, and containing a few small lamellibranchs. In the grounds of "The Glenfall," the picturesque waterfall, depicted in Prof. J. Buckman's "Botanical Guide to the Environs of Cheltenham, etc.," is caused by the presence of the Marlstone.

Above Southam there is an exposure of typical Marlstone. The section is somewhat difficult to find: the best way to reach it is to take the path which leads up to the cottages below the quarried face of the hill, but to turn to the left along the west side of the wood, when the outcrop of the "rock-bed" will be observed constituting a little promontory at the north-west corner. Here *Amaltheus margaritatus* and *Paltopleuroceras sp.* occur; the other fossils procurable being *Gryphæa cymbium* (young), *Protocardium truncatum*, *Isocardia liassica*, and an occasional specimen of *Belemnites paxillosus*.

East of Wood Stanway, near Winchcomb, there is a noticeable little knoll, separated from the main hill-mass by a, relatively speaking, deep valley. This knoll is capped by Marlstone, exposures of which may be observed in the road leading up from the village, and again a few yards to the north of where it commences to descend into the afore-mentioned valley.

To return to the Painswick area, we have occasional exposures of the Marlstone in the deep valley which bifurcates near that town. On the Stroud and Painswick road at Rock Mill it is well exposed, being a light-brown sandy rock, with a few belemnites and other fossils. Then there is an equally good section about 550 yards south-south-west of Painswick Church, where the beds are seen to be somewhat flaggy, and such is the case in

the sections above Baylis's Mill, and in a lane-cutting 250 yards to the north again. In the deep lateral valley near Comb House the outcrop of the strata in the bed of a stream give rise to a succession of little waterfalls: and the rock is also well exposed in the banks of the stream in the valley 550 yards to the west-north-west of Highfold. In the other valley which lies to the east of Painswick the "rock-bed" is seen dipping 45 degrees east in the lane-cutting east of Cox's Mill (a little over a mile north-east of Painswick Church). Mr. Charles Upton directed my attention to a section near Loveday's Mill. It is reached by proceeding a short distance up the valley from the road near the Mill, along the east bank of the stream. The Upper Lias is also visible.

THE UPPER LIAS, COTTESWOLD SANDS, AND CEPHALOPODA-BED.

Although there is a very considerable development of the Upper Lias in this neighbourhood, it is extremely difficult to obtain sections. In addition to the *prima facie* probability that an argillaceous deposit between two rocky and more prominent formations should seldom appear otherwise than by surface indications, must be added the fact that its outcrop area is often concealed under tumbled oolite: a phenomenon which may be readily observed on the north face of Bredon Hill, and that portion of the Cleeve-Hill escarpment overlooking Southam. Although the position of the Upper Lias in the escarpment in this district prevents the clays from being dug for brick-making, the deposit is of considerable economic value in connection with the water-supply. The superincumbent strata of the Inferior Oolite are essentially water-bearing: the water being supported by the Upper Lias clay, which throws off many springs along the escarpment, and from isolated hills. Consequently, in addition to differential denudation, which has revealed the position of the outcrop area by removing the clay at a more rapid pace than the superincumbent

Inferior Oolite and subjacent Marlstone, the presence of the Upper Lias Stage can often be detected by the outburst of water, either in the form of springs or as indicated by rushes and wet ground. Wet ground attributable to this cause may be observed on the north side of Birdlip Hill, on the north-west slope of Stanley Hill, above Stanley Pontlarge, and many other similarly-situated localities. The springs thrown off are numerous, and, as might be expected from the prevalent south-easterly dip of the deposits, the greater number flow in that direction. On the escarpment, springs flowing westwards may be noticed near Knoll Hill Farm (about a mile north-east of Prestbury); at "The Glenfall;" on the west flank of Crickley Hill, where a small spring bursts out near the cottage; and near Gunnis Farm, west of Edge; whilst on the outliers capped by the Inferior Oolite springs are noticeable an the south-west side of Oxenton, and on the north slope of Bredon. The Seven Springs, those at Ullen Wood, Puckham, Syreford, and Pinchley Grove, are examples of springs thrown off the clay, and flowing more or less with the dip. The sites of many of the isolated houses and villages in the Cotteswold country are determined by the position of the Upper Lias: either they are situated on it, or it can be reached by means of wells sunk through the Oolite.

As will have been gathered from the above reference to the water supply, the lithic character of the Upper Lias is essentially argillaceous. The series in this district consists of blue clay, with occasional nodules of bluish-limestone, the clay becoming in places considerably arenaceous towards the top.

The upward extension of the Upper Lias has been, and to some extent is still, a source of much debate. The old school of geologists placed much reliance upon lithic structure in correlating various sections. Now as there is often present between the clays of the Upper Lias and the limestones of the Inferior Oolite an arenaceous deposit capped by a marly limestone—the arenaceous deposit and the marly limestone being known in

Gloucestershire as the Cotteswold Sands and Cephalopoda-bed respectively—accordingly, when a similar deposit as regards lithic structure was observed in other localities occupying approximately the same stratigraphical position, a local term was applied, and the rocks correlated with the Gloucestershire beds. Thus, according to the old interpretation, the Cotteswold, Midford, and Yeovil Sands were contemporaneous, but, as Mr. S. S. Buckman has clearly shown, such is not the case. That author has subdivided the "Sands" and Cephalopoda-bed into eight zones, or, more correctly speaking, he has found out that these deposits were laid down during eight hemeræ, namely, those of *opaliniforme*, *aalensis* *Moorei*, *Dumortieria*, (characterized by *Dumortieriæ* of various species,) *dispansum*, *striatulum*, *variabilis*, and *Lilli*. Taking the *striatulum*-beds as a fixed datum-line, Mr. Buckman shows that the Cotteswold Sands, deposits of the hemeræ *variabilis* and *Lilli*, are below that line; that the Midford Sands (typical area, Bath), with the *striatulum*-beds at their base, and mainly characterized by ammonites of the *dispansum*-beds, are above the fixed datum-line; whilst the Yeovil Sands, with *Dumortieriæ*, overlie the *dispansum*-beds, and are, therefore, of still later date. By some authors the deposits formed during the hemeræ of these ammonites have been considered as Liassic, by others as Oolitic; whilst others, again, would regard them as "Transition-beds." The deposits laid down during the hemeræ *opaliniformis*, *aalensis*, and *Moorei*, have often been regarded as composing the lowest zone of the Inferior Oolite, that commonly known as the "*opalinum*-zone"; whilst those formed during the hemeræ *Dumortieriæ*, *dispansi*, *striatuli*, and *variabilis*, have been described under the denotation, "*jurense*-zone," and grouped with the Upper Lias. Mr. Charles Upton has observed, that "we are on perfectly safe ground in stating that the strata above the Opalinum zone are Inferior Oolite."

* "Quart. Journ. Geol. Soc.," Vol. XLV. (1889), p. 440.

However, it would seem that from a palaeontological standpoint the break comes between the sediment laid down during the hemera *aalensis* and that deposited during the hemera *Moorei*. For the present purpose, therefore, the Inferior Oolite Series is considered to commence with the *aalensis*-beds, and the Upper Lias to end with the *Moorei*-beds. The International Congress considered that the division should be arbitrary between the *opalinum*- and *jurense*-zones, and this carries out their idea, but with further refinement. For purposes of convenience, however, the *opaliniforme*- and *aalensis*-beds are dealt with in the present chapter.

On Robins' Wood Hill the Upper Lias is not clearly exposed, but its superficial extent can be easily determined. Two wells sunk in the clay supply the neighbouring brickyard with water: the water-bearing beds being a considerable thickness of Cotteswold Sands, capped by the basement beds of the Inferior Oolite Series.

Churchdown Hill is capped by the lowest beds of the Upper Lias, and a detailed account has been furnished by Dr. Smithe.* The following details were noted in October, 1902 :—

Quarry on Churchdown Hill.

		Ft.	Ins.
	Subsoil	1	2
Upper Lias.	1. Blue and brown marl	1	0
	2. Nodules of argillaceous limestone; *Pseudolioceras* (ammonite), fish remains, and small gasteropods	0	4–6
	3. Blue and brown, marly shales	7	0
	4. Arenaceous marl (*Leptæna*-bed of Dr. Smithe), *Terebratula globulina*	0	7–11

* "Proc. Cotteswold Nat. F.C.," Vol. III. (1865), p. 40; *Ibid.*, Vol. VI. (1876), p. 374.

		Ft.	Ins.
Middle Lias.	5. Nodules of argillaceous limestone; *Belemnites* spp., gasteropods	0	6
	6. Yellow, calcareous sandstone, soft; full of *Belemnites* and *Plicatula spinosa*, passing downwards into a more compact rock, containing *Belemnites paxillosus*, *Rhyn. tetrahedra*, *Aulacothyris resupinata*, etc.; visible	6	0

There are two outliers of the Upper Lias at Oxenton, both of which are capped by Inferior Oolite. The presence of the Upper Lias, however, is only indicated by the outburst of springs and wet ground. Crane Hill, that portion of Oxenton overlooking the village of Woolstone, is affected by three faults. Standing upon this hill, and looking up to the superior height of Oxenton Hill proper, a relative estimate may be obtained of the amount of depression to which this faulting has subjected Crane Hill. On the latter hill (400 feet) we stand on rocks of the same age as those which cap Oxenton Hill (734 feet).

The best section of the Upper Lias in this district—but it is becoming rapidly overgrown—is on Alderton Hill. The literature descriptive of the sections once seen here afford ample evidence of their importance.* The deposits, which comprise finely-laminated blue shales, with lines of flat nodules, contain in some abundance remains of fish and insects, on which account Prof. Judd† once suggested the term "Dumbleton Series" for the beds. The limestone-nodules may be seen a little below the turf, whilst on the talus-heap—or sloping

* "The Geologist," Vol. I. (1858), p. 230; "Fossil Insects" (1845), p. 55; "Quart. Journ. Geol. Soc," Vol. V. (1849), p. 32; "Proc. Cotteswold Nat. F.C.," Vol. II. (1860), pp. 133, 134; *ibid.*, Vol. I. (1853), p. 268; Murchison's "Geology of Cheltenham" (1844), pp. 35, 36; "Proc. Cotteswold Nat. F.C.," Vol. VII. (1880), p. 149; *ibid.*, Vol. X. (1892), p. 202; "Geological Magazine," Dec. III., Vol. III. (1886), p. 108; "Mem. Geol. Surv. 'The Jurassic Rocks of Britain,'" Vol. III. (1893); "The Lias," pp. 266, 267.

† "Mem. Geol. Surv., 'The Geology of Rutland'" (1875), pp. 58, 79.

accumulation of débris—against the face of the old quarry, are pieces of brown fissile rock also full of such remains. A diligent search over the spoil-heap will reward the observer with specimens of *Terebratula globulina* and *Rhynchonella pygmæa*, together with numerous small ammonites, and, occasionally, fragments of *Belemnites* spp.

The great outlier of Bredon Hill has recently afforded very interesting information in connection with the beds under consideration. Mr. H. H. Howell estimated the thickness of the Upper Lias here at 100 feet, or more.* Several years ago, however, Mr. Buckman obtained ammonites indicative of deposits laid down during the hemera *dispansi*. These ammonites of a *dispansum*-type were found below the brow of the northern flank of the hill. More recently, evidence has been obtained that beds were deposited in the Bredon area during the hemeræ *Lilli*, *variabilis*, *dispansi*, *Dumortieriæ* and *Moorei*. The finding of ammonites of a *dispansum*-type and other fossils which enable it to be stated that certain deposits are present at Bredon Hill is important for several reasons. On the Geological Survey Map the Inferior Oolite is represented as resting directly upon the Upper Lias without any intervening "Midford" or Cotteswold Sands. But at Haresfield Beacon, as will be shown shortly, the Cotteswold Sands were deposited during the hemerae *variabilis* and *Lilli*, and are overlaid by the Cephalopoda-bed—a deposit accumulated during the hemerae *opaliniformis*, *aalensis*, *Moorei*, and *Dumortieriæ*. Here at Bredon Hill, however, the *scissum*-beds (Inferior Oolite) rest directly upon clay. The fact is, that at Bredon, clay (with a few limestone-nodules) was being deposited, while sand and marly limestone were being laid down in the Haresfield area. Taking this latter fact into consideration, we see that because an easily-recognised bed of the Inferior Oolite

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* "Mem. Geol. Surv., 'The Geology of the Country around Cheltenham.'" (1857), p. 24.

Series is found resting upon a clay at a certain locality, it does not follow that that clay must be of the same date, and that the "Transition-beds" are wanting.

About a mile west-north-west of Winchcomb is the outlier of Stanley Hill, where—in addition to the usual surface indications of the presence of the Upper Lias—there is a small exposure half-a-mile to the south of Gretton. The section now afforded is similar to that on Alderton Hill, the "Fish-bed" being visible just below the turf.* The fossils, which are rare, include belemnites, small gasteropods, and fragments of ammonites of an *annulatus*-type.

Although just outside the district under review, the section at Haresfield Beacon may be mentioned as a good locality for studying the Cephalopoda-bed and Cotteswold Sands; but, as will be seen upon referring to the following description, deposits of the hemeræ *dispansi* and *striatuli* are wanting.† Mr. S. S. Buckman has kindly allowed me to incorporate certain of his unpublished notes (which I have verified) in the following section. The abundance of a so-called *Rhynchonella cynocephala* in these beds led Dr. Lycett, in 1857, to make use of the term "Cynocephala stage" for both the Cephalopoda-bed and the Cotteswold Sands.‡

GENERALIZED SECTION OF THE ESCARPMENT OF HARESFIELD BEACON.

		Ft.	Ins.
Inf. Oolite.	1. Pea-grit; *Rhynchonella subangulata, Rhyn. oolitica, Ter. plicata*	5	0
	2. Lower Limestone	38	9
	3. *Scissum*-beds; *Rhyn.* cf. *subdecorata* (small), *Myacites*	7	8

* "Proc. Somerset Arch. and Nat. Hist. Soc.," Vol. XIII. (1867), p. 148.

† "Monograph of the Inferior Oolite Ammonites of the British Islands," Pal. Soc. (1888), pp. 43, 44; " "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,' " Vol. IV. (1894); "Lower Oolitic Rocks of England," p. 122.

‡ "The Cotteswold Hills" (1857), pp. 16, 18.

Cotteswold Sands and Cephalopoda-bed.		Ft.	Ins.
	4. *Opaliniforme*-beds. Hard ironshot limestone ; *Cypholioceras opaliniforme, Lioceras comptum*	1	0
	5. *Aalensis*-beds. Hardish yellow rock ; *Pleydellia aalensis*	0	4
	6. *Moorei*-beds. (*a*) Brown marl ; *Dumortieria Moorei*, " *Rhynchonella cynocephala*," *Belemnites* spp. ..	0	6
	(*b*) Dark-brown marl, full of " *Rhynchonella cynocephala*," *Rhyn. cotteswoldiæ*, etc.	0	1–2
	7. *Dumortieria*-beds. Yellowish-brown marl ; *Terebratula haresfieldensis* abundant, and *Rhynchonella cynoprosopa**	0	10
	8. *Variabilis*- and *Lilli*-beds. Cotteswold Sands. Yellow, micaceous sands, with sandstone band	190	0
Upper Lias.			
	9. Clay	130	0

The only useful exposure there is of typical Cotteswold Sands in the district under consideration is in a deep lane-cutting west of Edge and south of the Horsepools. The sands here contain very fine mealy beds, which—according to Mr. W. C. Lucy—were formerly used for cleaning silver. Proceeding down this lane, the junction of the Cotteswold Sands and Upper Lias clay is plainly indicated by a spring of beautifully clear water.

Following the outer escarpment in a north-easterly direction, we find sections to be few and far between, and it is not until we arrive at Cooper's and Crickley Hills that argillaceous deposits are clearly seen. At the former locality blue clays are visible in an old quarry near the cottages, whilst a little to the south-west, but higher up the hill-side, a deposit of yellowish sand is seen below the *scissum*-beds. At Crickley Hill there is a small

* *Vide* " Quart. Journ. Geol. Soc.," Vol. LI. (1895), pp. 450, 451.

exposure of somewhat micaceous clays in the wood at the back of the cottages, just before rounding the point. Dr. Thomas Wright has collected "*Hildoceras bifrons*" in brownish marl at the southern base of this hill.

In the side of the bridle-road just beyond the house known as "Firs Brake," on Leckhampton Hill, there is a good exposure of clays becoming considerably arenaceous towards the top, and from the somewhat shaly beds good specimens of *Belemnites* spp. may be occasionally obtained. At the extreme western end of Charlton Common the clays are capped by sands closely resembling lithically the Cotteswold Sands of the Edge section. On Wistley Hill a portion of the ammonite *Lillia Lilli* was obtained from a hard bluish-black limestone-nodule embedded in the clay. Now at Coaley Wood, near Stroud, strata of this date consist of a hard, yellowish-blue, calcareous sandstone, intercalated in fine yellow sands (Cotteswold Sands),* so that the lesson again enforced is the variability in lithic structure of deposits which are known to be contemporaneous. Moreover, this "find" at Wistley Hill prepares us for the fact that at Bredon Hill we have to deal with a clay deposit as the accumulation laid down during some, if not all, of the hemeræ in which the Cotteswold Sands and Cephalopoda-bed were deposited. The clays are also visible in the prominent spur of the hill above Vineyard's Farm.

On the north side of the Chelt Valley, blue clays—presumably Upper Lias—are well exposed near Puckham Farm.

Continuing along the outer escarpment, we see the usual indications of the presence of the Upper Lias below the quarried face of Cleeve Hill, and frequently the clay itself is visible.

Near the washpool in the Postlip Valley it is very fairly exposed. East of Winchcomb the little hamlet of Chapel Farmcote nestles under the scarp of the hill, and follows the line of junction of the clays with

* "Quart. Journ. Geol. Soc.," Vol. XLV. (1889), p. 444.

the oolitic beds. In the valley north of Cassey Compton, near Chedworth, the clay is very much in evidence. Blue clays occupy the centre of an anticlinal flexure in the railway-cutting not far from the Frog Mill Inn — the third cutting from Andoversford. That at Withington Station was wholly excavated in Upper Lias clays, but, as might be expected, it was soon overgrown.

"The outrush of water from the Seven Wells, the beautiful source of the Churn, constitutes at once a small rivulet, which issues from the lower part of the oolite, and soon is found running over Lias clay,* "and continues to do so for the greater part of its course to Rendcombe.

Returning now to the Painswick Valley, we find but few exposures of the deposit under consideration. It was well exposed during the construction (1902) of a road a little to the south-east of Painswick Church, and the writer has seen it in the sides of a lane leading from the Painswick and Stroud road, near King's Mill, to the locality marked as Jenkins' Farm on the Survey Map: and again, about a quarter-of-a-mile south-east of Holcombe. Indications of the Cotteswold Sands and Cephalopoda-bed were observed in the south side of the lane leading from Wick Street to Small's Mill. In the Slad Valley, however, there are three very fair sections. The first is in the lane to the west of Steanbridge, where the clays are capped by an arenaceous deposit—probably the equivalent of the Cotteswold Sands, but which does not appear to exceed 25 feet in thickness; the second, to the east of the bridge, and also in a lane; whilst the third is to the north, in the left-hand side of the road leading to Down Farm, about 300 yards distant from the bridge. Here we have a hard blue and brown, somewhat ferruginous band of rock interstratified in the clays.

Running in a northerly direction from Edgeworth is a deep valley, which bifurcates about half-a-mile south of Caudle Green, the north-western extension being known as the Climperwell Valley. In the banks

* "Geology of Oxford and the Valley of the Thames" (1871), p. 30.

of the streams flowing along the bottoms of these valleys we have occasional glimpses of the Upper Lias clay. A very picturesque spot is Climperwell. Although we cannot actually see the clay here, its presence is very clearly indicated by two strong springs. In February, 1903, clay was very well exposed in the bed and sides of the streamlet which flows along the north side of the road leading east-north-east from the cottage in the valley at Bull Bank Common, near Miserden.

The historical geology of the epoch during which the Liassic beds were accumulated now requires attention. At the commencement of the epoch the main physiographic features were similar to those of the preceding Rhætic Epoch, but the early Liassic sea soon encroached upon the coast-line formed of Palæozoic and Pre-Cambrian rocks. In the railway-cutting at Lassington, near Gloucester, there is a remanié-bed—that is, a bed containing, in addition to the examples of the fauna and flora of the time when it was formed, derived rock and fossils from certain underlying deposits. A nodule in the Worcester Museum, obtained from Sarn Hill, near Tewkesbury, probably occupied the same stratigraphical position as the Lassington remainé-bed. Thus, to quote Mr. H. B. Woodward, "it [*i.e.*, the Lassington remanié-bed] indicates, however, some change in conditions, like the bottom bed of Lias noticed at Stormy Down, near Bridgend, and the 'Guinea-bed' of Warwickshire," and he considers it to suggest a slight unconformable overlap of the Lias. According to Mr. A. J. Jukes-Browne, we may "assume that during the formation of the Lias the coast-line ran from the eastern border of Dean Forest to Malvern, the gaps which now intervene between the higher elevations being due to post-Jurassic erosion." "The deposition of so great a thickness of dark-coloured clay and shale in Liassic times is another point that calls for explanation, and it may be fairly assumed that this material was mainly supplied by the destruction of the Coal-measure shales. Large tracts of Coal-measures must have existed at this time both in

Ireland and Scotland, and the rivers flowing off these tracts would pour little else than black mud into the surrounding sea, while the waves would eat deep into such portions as came within their reach during the gradual submergence." The nature of these deposits, and the conditions under which they were formed, were such as favoured the preservation of examples of the fauna and flora of the epoch. In Liassic times a moderately deep sea, teeming with living creatures, spread over our district. That there were minor movements of the sea-floor appears probable. If the identification of the specimens be correct, the commingling of *Paltopleuroceras spinatum* and *Amaltheus margaritatus* at Cleeve and Bredon Hills—which in most localities characterize distinct deposits—would seem to indicate either that the sea was somewhat shallow, or that there was paucity of sediment. During the deposition of the Upper Lias the sea was deeper, but towards the close of the epoch the absence of sediment in this area, laid down during certain hemeræ, during which beds were accumulating in others, would suggest slight upheavals of the sea-floor. The lithic structure of the rocks formed during late Liassic times is variable; for, as we have already seen, in the neighbourhood of Haresfield a great thickness of sand was accumulating whilst clay was being deposited at Bredon. As far as is at present known, there is evidence to show that there was an upheaval (an anticlinal flexure) in the Birdlip area, in post-*variabilis* pre-*scissi* times, that is, after the formation of the Cotteswold Sands. This anticline suffered erosion, so that at Haresfield there is a great thickness of Cotteswold Sand capped by the Cephalopoda-bed; whilst at Cooper's Hill nearly all the sand has gone, and there is no evidence of the Cephalopoda-bed.*

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* "Proc. Geol. Soc.," No. 779 (1903), p. 108.

Table III.—The Inferior Oolite Series (Cotteswold Hills).

	Geological Survey.	Approximate Zonal Terms used by Wright and Witchell.	Stratagraphical Terms.	Chronological Terms (After S. S. Buckman). Hemera.	Age.	Epoch.	Renevier's Chronographic Subdivisions.
Inferior Oolite Series.	Upper Stage.	*Parkinsoni*-zone.	Limestone beds above the *Clypeus*-grit (White Limestone.)	*fuscæ.* *zigzag.*	Parkinsonian.	Stepheoceratidan.	Bathonian.
			Clypeus-grit.	*Truellii.*			
			Upper *Trigonia*-grit.	*Garantianæ.*			
			non-sequence.				
		Humphriesianum-zone.	*Phillipsiana*-beds.	*Sauzei.*	Sonninian.		Bajocian.
			Bourguetia-beds.				
			Witchellia-grit.	*Witchelliæ.*			
			Notgrove Freestone.				
			Gryphite-grit.	*Sonniniæ.*			
			Buckmani-grit.	Post-*discitæ.*			
			Lower *Trigonia*-grit.	*discitæ.*			
			Upper Snowshill Clay.		Ludwigian.	Arietidan.	Aalenian.
			Tilestone*				
			Lower Snowshill Clay.*	*concavi.*			
			Harford Sands.				
			Blockley Clay.*				
	Lower Stage.	*Murchisonæ*-zone.	Upper Freestone.	*bradfordensis.*†			
			Oolite Marl.				
			Lower Freestone.	*Murchisonæ.*			
			Pea-grit.				
			Lower Limestone.				
			scissum-beds.	*scissi.*			
		opalinum-zone.	*opaliniforme*-beds.	*opaliniformis.*			
			aalensis-beds.	*aalensis*			
			Moorei-beds.	*Moorei.*			

* Found only in the North Cotteswolds. † Over a considerable portion of the district there is a non-sequence between (1) the deposits of the hemerae *discitæ* and *bradfordensis*; and (2) between, apparently, the deposits of the hemera *scissi* and the subjacent beds.

CHAPTER V.

THE INFERIOR OOLITE.

Resting upon the Upper Lias is the series of rocks which has justly rendered the Cheltenham district so famous amongst geologists. This series, stratigraphically, is known as the Inferior Oolite,* and occasionally it has been spoken of as the Bajocian. This latter term, however, has also been used as a chronological one, to denote the time during which only certain subdivisions of the Inferior Oolite were deposited. The term, "Under Oolite," was applied by William Smith to what we now know as the Inferior Oolite, but this latter denomination, published by Townsend in 1813, was also suggested by Smith, and adopted by Sowerby in 1815. The reason that Smith distinguished these rocks under the names of "Under" or Inferior Oolite was, that in Somerset—whence the classification of the strata was taken—they underlie the locally more important Great or "Upper" Oolite.

In the neighbourhood of Cheltenham the Inferior Oolite attains the great thickness of about 300 feet,† and constitutes the summits of the Cotteswolds over a very considerable area. Seldom is a series of rocks better known as regards the fossil contents of the various subdivisions, the history of those subdivisions, and their present geographical distribution. This is, in the main,

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* The term "Cheltenham Beds" has been employed by Sir A. Geikie for the Inferior Oolite. "Text Book of Geology," ed. 2 (1885), p. 788.

† At Leckhampton Hill its thickness is stated to be about 236 feet; and at Cleeve Hill about 304 feet.

due to the excellent work accomplished by Mr. S. S. Buckman, who has embodied the results of his investigations in three papers communicated to the Geological Society of London, and published in their *Quarterly Journal.*

In this neighbourhood the Inferior Oolite admits of the divisions given in Table III. In that table are tabulated the stratigraphical and chronological terms. It, moreover, shows the use to which the term Bajocian should be restricted, namely, as a chronographic term. The chronological terms are of universal application, but the stratigraphical ones are only of local value. For example, deposits laid down during the hemera *Murchisonæ* in this district consist of false-bedded oolite and layers of coarser oolite and pisolite ; but if it was wished to find their equivalents by means of their lithology in Normandy there would be considerable difficulty, for there the beds of the hemera *Murchisonæ* are clay deposits, like our typical Upper Lias clay. But if it was desired to find the equivalent deposit—using this term in its true geologic sense—there would be, comparatively speaking, little trouble, for the zonal ammonite, whether it be embedded in an argillaceous or a calcareous deposit, is a true indicator of time : hence the value of chronological terms.

Ammonites are very abundant in the Inferior Oolite of Dorset, but rare in the Cotteswolds, except at one horizon (*Witchellia*-grit), and even there they cannot be said to be numerous. A sufficient number, however, have been procured from the several beds to enable us to refer the deposits to their correct stratigraphical positions, but when this had been done a detailed examination of the brachiopods peculiar to these beds was made, so that they—being a more-abundantly represented class—might be used for correlating the various sections : a function which ammonites serve in the Dorset-Somerset area. At Cold Comfort, for instance, *Terebratula Wrighti* is found to occur in association with ammonites mainly of the genus

Witchellia; accordingly, if we found that brachiopod somewhere else in the Cotteswold country we should have little hesitation in saying that the deposit from whence it was obtained was of the hemera *Witchelliæ*.

Although the fauna yielded by the Inferior Oolite is a rich one, the remains are chiefly invertebrate, those of the vertebrates being exceedingly scarce. As already mentioned, few ammonites are to be found on the Cotteswold Hills, but examples of Nautili, which belong to the same class, may often be seen in the Rolling Bank Quarry on Cleeve Cloud: some of them attaining such large dimensions that it is scarcely possible for a single person to move them. Gasteropods are fairly numerous, lamellibranchs still more so, but by far the most abundant are the brachiopods. Encrusting many of the larger mollusks are the pretty polyzoa, popularly known as "sea-mats"; and, occasionally, the calcareous tubes of annelids. Echinoids were very common when the beds (Pea-grit) in which they mainly occur were worked, but now they are by no means so frequently seen on the spoil-heaps. Corals are plentiful at certain horizons, there being at least four well-marked coral-beds in the Cotteswolds. Remains of crustaceans are very rare, but they may be sometimes found in the Pea-grit. The plant-remains include ferns, conifers, and cycads, but of these, again, very few specimens have been obtained.

THE *SCISSUM*-BEDS.

At Haresfield, it will be remembered, there are 7 feet 8 inches of strata capping the Cephalopoda-bed, and such were laid down during the hemera *scissi*—the characteristic ammonite, *Tmetoceras scissum*, being most distinctive but rare. As Edwin Witchell observed, this deposit "is persistent throughout the greater part of the Cotteswolds," and he named it the "sandy ferruginous limestones."* At Haresfield, beds of this

* "Quart. Journ. Geol. Soc.," Vol. XLII. (1886), p. 268.

date contain few fossils, and the brachiopods are very poorly represented—an occasional *Rhynchonella* of the *subdecorata*-type (very small) being all that has rewarded my investigations. On Robins' Wood Hill, however, a small form of *Rhynchonella subdecorata* is by no means uncommon, but the exposures whence they are obtainable are very indifferent, being in the path on the summit of this conspicuous outlier. Probably these fossils have come from a bed at the base of the Pea-grit, as they are of the same form as those found at Cud Hill, near Painswick. From Robins' Wood Hill the writer has also collected *Aulacothyris Blakei* and *Rhynchonella cynocephala*. On Bredon Hill these beds comprise brown arenaceous strata, very ferruginous in places, and becoming more compact towards the base. One mile north-west of Overbury Church there is a large quarry in which these sandy beds are well exposed. The promontory separating that portion of the quarry now worked from that which is disused is composed of *scissum*-beds, capped by flaggy, yellowish-white, oolitic limestone. In the western face of that portion of the quarry now worked, the Pea-grit-equivalent and Lower Freestone are faulted against the sandy beds: the last-named deposit being also traceable along the south face of the same portion of the quarry. The fossils procured from here were *Terebratula euides*, *Rhynchonella cynocephala*, and a few *Belemnites* spp. The *scissum*-beds are exposed for a thickness of 13 feet in the above-mentioned promontory, and from the point where they are obscured by talus to the floor of the quarry is about 7 feet; whilst from this point again to the water-retaining bed is another 8 feet. Thus, from the top of the arenaceous strata to the water-retaining bed is about 28 feet.* Opposite Kemerton Castle,† and again in the spinney about two hundred yards to the north-west, the same deposits are well exposed. At the latter place their thickness was estimated at 33 feet.

* "Geol. Mag.," Dec. IV., Vol. IX. (1902), pp. 513, 514.
† "Mem. Geol. Surv., 'The Geology of Rutland'" (1875), p. 14.

Both Crane Hill and Oxenton Hill proper are capped by the *scissum*-beds, but the strata are in a most disturbed condition, and occur chiefly in the form of rubble. With rock of this date is mixed much rubble of Lower Limestone and Pea-grit. On a rabbit-warren on the west flank of Crane Hill the writer has obtained *Terebratula withingtonensis*, *Ter. plicata*, *Ter. euides*, *Rhynchonella subdecorata* (large). *Rhyn. subangulata*, *Aulacothyris Blakei*, *Montlivaltia* (a coral), *Gryphæa*, *Serpula*, and *Belemnites* spp.—the brachiopods being indicative of the *scissum*-beds and Pea-grit. Specimens of very fine *Rhynchonella cynocephala* var. may be obtained here, and those of *Rhyn. subdecorata* are also unusually large, but the tests of the latter are seldom well-preserved. From the *scissum*-beds at this locality has been collected *Hammatoceras* cf. *Newtoni*. On Stanley Hill, *Rhynchonella subdecorata* and *Terebratala euides* have been obtained from the strata exposed in the side of the path leading from the summit of the hill down to Stanley Pontlarge, the exposure of the beds being in the wood.*

Returning to the Painswick area, we find the *scissum*-beds exposed in quarries on Cud Hill, and they are also visible in several smaller exposures to the east. *Rhynchonella* cf. *subdecorata* (small) is somewhat abundant at this locality in a certain bed at the base of the Pea-grit; and a *Terebratula* somewhat resembling a large form of *Ter. euides* is not uncommon in the *scissum*-beds. On Cooper's Hill the whole thickness of the *scissum*-beds is exposed, being 12 feet 2 inches thick, and containing *Rhynchonella subdecorata* (large), *Rhyn.* cf. *subangulata*, *Terebratula euides*, *Pecten*, and *Myacites*. The under-surface of the bottom-bed—immediately above the fine yellow sands, which are exposed for a thickness of two feet—is covered with *Belemnites* spp. It is possible that this layer with belemnites may represent a bed exposed in

* The hill to the south of Gretton is often spoken of as Stanley Mount, but to be correct, the name Stanley Hill should be restricted to the western portion, and the name Langley Hill to the eastern.

the third cutting on the line from Andoversford to Chedworth, which will be described when dealing with that section (page 72). Above the *scissum*-beds at Cooper's Hill, and resting upon their bored surface, are the massive beds of the Lower Limestone capped by rubble of typical Pea-grit. From the Pea-grit at this locality have been obtained *Acrosalenia Lycetti*, and *Galeropygus agariciformis;* also corals. "Four beds of ferruginous sandy limestone," having a thickness of 6 feet 3 inches, have been noticed by Witchell at the western end of the quarry on the south face of Crickley Hill.

The wall along the south side of the Green Way is built out of rock of the hemera *scissi*: the weathered stones being often covered with *Rhynchonella cynocephala*, and, less commonly, with *Aulacothyris Blakei*. At the "Firs-Brake" section the beds under consideration are seen above the clay, but appear to have slipped a little. Here they contain *Tmetoceras scissum*, *Trigonia*, *Terebratula* cf. *euides* (large), *Rhynchonella* cf. *subdecorata* (very small), and *Aulacothyris Blakei*. On the spur of Wistley Hill, overlooking Vineyards Farm, the same beds are well exposed, and are replete with *Belemnites* spp. *Rhynchonella cynocephala*, *Aulacothyris Blakei*, *Terebratula euides*, and *Rhynchonella subdecorata*, also occur.

On the Cleeve Hill plateau there is an excellent section near the stream at Puckham Farm. Here one stratum, in particular, is full of *Rhynchonella cynocephala*, but the rock is very hard, and consequently, there is some difficulty in extracting the specimens without damaging the beak: that is, that portion of the shell in which is situated the aperture through which the fleshy cord or *peduncle* passed which moored the mollusk to the rock or other object. Besides this fossil, *Aulacothyris Blakei* is by no means uncommon, and a *Terebratula* somewhat resembling the species *haresfieldensis* has been found. The lamellibranchs are also moderately represented. Care should be taken at this locality in assigning fossils not found *in situ* to the *scissum*-beds, as many brachiopods have rolled down from the rubble of Pea-grit which

caps the bank. In fallen pieces of rock on the Upper Lias exposure near the washpool in the Postlip Valley, and often loose, may be found many fossils belonging to the *scissum*-beds, such as *Aulacothyris Blakei*, *Rhyn. cynocephala*, *Rhyn. subdecorata* (large), a *Terebratula*, and *Belemnites* spp.

Between Stanway Hill and Syreford there are no definite sections of the *scissum*-beds, unless, as is probable, their representatives be those brownish sandy rocks, yielding *Belemnites* spp. somewhat abundantly, which were formerly exposed below the Pea-grit-equivalent in Spoonley Wood—forming part of a slipped mass. Upon referring to the Geological Survey Map, we might have expected to find the *scissum*-beds sectionized in the railway-cutting near Syreford, but, as pointed out by Mr. S. S. Buckman, such is not the case: the cutting reveals a coarse freestone and a yellowish sandy deposit, which should probably be referred to the top of the Pea-grit series. On the Midland and South-Western Junction Railway, in the third cutting from Andoversford, an interesting section is presented. It will be noticed that the Geological Survey Map shows the spur through which the cutting passes as being composed of Upper Lias.* In the cutting is a small anticline, in which the Upper Lias is thrust up amongst the basement beds of the Inferior Oolite. The section has been briefly described by Mr. Buckman,* and again in greater detail by Mr. E. B. Wethered, F.G.S.†

From these two records the following details may be given:—

THIRD CUTTING FROM ANDOVERSFORD.

	Ft.	Ins.
Pea-grit. 1. Shelly, and crystalline limestone, with large granules; *Terebratula submaxillata*		
Lower Limestone. 2. Irregular beds of limestone, mixed with marl	10	0

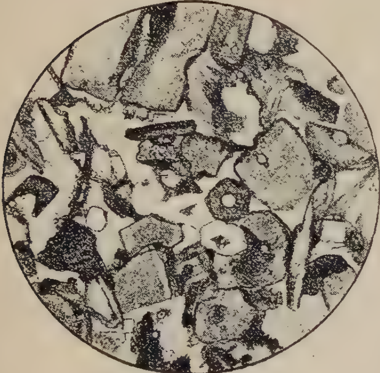
* "Proc. Cotteswold Nat. F.C.," Vol. X. (1892), pp. 96, 97.
† "Quart. Journ. Geol. Soc.," Vol. XLVII. (1891), pp. 551, 552.

	Ft.	In.
Scissum-beds. 3. Several beds of yellow sandy, limestone ; *Rhyn. subangulata*, *Rhyn. subdecorata*, *Rhyn. cynocephala*, *Terebratula perovalis* [cf. large *euides ?*], *Terebratula Etheridgii*, *Pholadomya fidicula*..	12	0
4. Calcareous bed..................	0	10
5. Sandy limestone ; *Belemnites* spp.	1	2
6. Crystalline limestone, light-coloured	0	6
Cotteswold Sands. 7. Brown and blue sands	5	0
Upper Lias. 8. Blue clay .		

It will be seen, then, that a deposit of blue and yellow or brown sand caps the Upper Lias, as at Charlton Common. The section, moreover, much resembles that obtainable at Cooper's Hill. Concerning Bed 6 of the above section, Mr. Wethered wrote : "Thin sections of it prove that the limestone is crystalline, and for this reason some of the organic remains are not determinable. Among those which could be made out are the ossicles of crinoids, spines, shell-fragments, and foraminifera. The first two are the most numerous, and the rock may be said to be largely made up of them." Fig. 1, pl. IV., is from a photograph of a microscopic section of this bed made by Mr. E. B. Wethered.

In a lane-cutting about one hundred yards north of Cassey Compton, or one-and-a-quarter miles east-south-east of Withington Church, the *scissum*-beds are exposed, and consist of brownish sandy limestones, yielding *Rhynchonella subdecorata*, *Rhyn. cynocephala*, and at the base many belemnites. Along the bottom of the east side of the valley to the north is much rubble of these beds, which contains *Belemnites* spp., *Aulacothyris Blakei*, *Rhyn. subdecorata* (intermediate size), and several lamellibranchs.

Following the valley of the Churn from the source of the stream down to Rendcombe, we find no definite exposure of the beds under consideration. The several stretches of water formed by the damming up of the stream, and which add so greatly to the picturesqueness of the valley, show at once where the water-retaining bed



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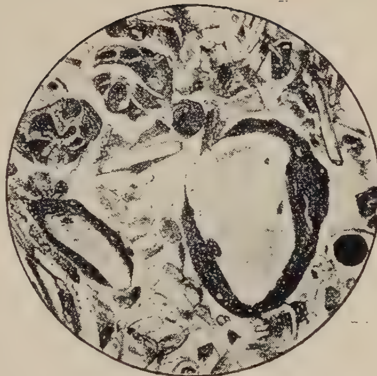

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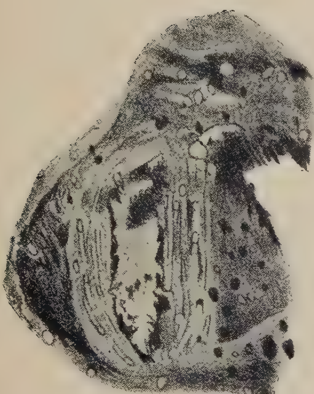

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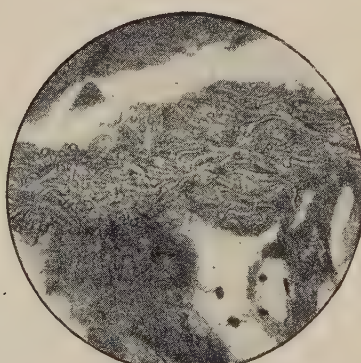

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FIG. 1.—Section of coarse limestone from near the base of the Pea-grit series. Shows it to be non-oolite, and to be largely made up of the ossicles of crinoids, and fragments of other echinoderms. × 12 diam. FIG. 2.—Section of semi-oolitic limestone from the Pea-grit series, a few feet above the spot from which the specimen represented in fig. 1 was collected. It shows that some of the fragments in the rock are coated with a crust made up of the tubules of *Girvanella*. These are illustrations of the oolite-granules which appear in the beds. × 12 diam. FIG. 3.—Portion of an oolite-granule from the Upper Freestone, near Chedworth, passing into the granular-crystalline condition. FIG. 4.—*Girvanella incrustans* var. *Lucii*, attached to a foreign object. From the Upper Freestone, Chedworth. × 70 diam. (E. B. Wethered.)

is, and in many places the clay is easily traceable well up the valley side—especially near the Mill at Cockleford. Clay is exposed in the north bank of the main-road a little to the north-east. It is always as well to keep a look-out for the *scissum*-beds wherever clay, occupying the stratigraphical position of the Upper Lias, is observed.

In the valley at Climperwell, south-west of Brimpsfield, the *scissum*-beds are well exposed near the springs, and comprise brownish arenaceous beds, in places greyish and somewhat crystalline. A *Terebratula*, in many respects resembling the species *haresfieldensis*, was noticed, but otherwise the beds seemed very barren. Above are massive beds belonging to the Lower Limestone, whilst capping these again, is typical Pea-grit.

THE LOWER LIMESTONE.

Above the *scissum*-beds in the neighbourhood of Stroud there are certain beds of freestone, from twenty to thirty feet thick, which were called by Witchell the Lower Limestone. At Haresfield this Lower Limestone has a thickness of about 38 feet 9 inches, and is quarried on the summit of the hill. From the well-known Cheltenham building-stone (Lower Freestone) it is distinguishable by its more crystalline structure. Sections of these strata are not numerous; the only good one near Cheltenham being that on Crickley Hill, which shows the passage of the beds under consideration into the Pea-grit proper. I say "Pea-grit proper," because it must be admitted that in many cases the line of division is somewhat arbitrary, for almost any beds between the *scissum*-beds and Lower Freestone may be pisolitic at one locality and non-pisolitic at another. The term, Lower Limestone however, was originally applied to those non-pisolitic beds which, as a rule, are present between the *scissum*-beds and typical Pea-grit.

Generally, they contain very few fossils, but at Crickley Hill, what is for the present regarded as the top bed of the Lower Limestone, is full of brachiopods, and

they are very fine examples. This particular horizon is four feet above the present (1903) floor of the quarry: the brachiopods yielded being *Pseudoglossothyris* (*Terebratula*) *simplex*, *Terebratula withingtonensis*, *Ter.* cf. *ventricosa*, Dav., *Aulacothyris* cf. *alveata*, and *Rhynchonella subangulata*. Witchell has recorded the following section* :—

SECTION AT CRICKLEY HILL, TAKEN AT THE WESTERN END OF THE QUARRY.

	Ft.	Ins.
(1) Pea Grit.		
1. Brown pisolite	4	0
2. Brown pisolite	3	0
3. Brown pisolite, thickness variable, about	5	0
4. Coarse oolite, subdivided by pisolite	7	0
5. Brown, coarse pisolite	5	0
6. Pisolite beds	11	0
(2) Lower Limestone.		
7, 8, 9, and 10. Four beds of oolitic limestone, composed of shelly detritus, fragments of spines of Echinida, and oolitic granules	8	6
11. Fine-grained oolitic limestone	1	9
12. Coarse-grained oolitic limestone	5	0
13. Coarse, brownish, oolitic limestone	2	6
14. Hard, brown, compact oolite	5	0
(3) Sandy Limestone.		
15, 16, 17, and 18. Four beds of ferruginous sandy limestone	6	3
(4) Cephalopoda-bed, not exposed.		

According to Mr. W. H. Hudleston "*Ptygmatis xenos*, Hudl., occurs sparingly in the shell-bed below the Lower Limestone on Crickley Hill, and this position justifies us in regarding it as the oldest species of *Nerinœa* discovered in Britain."†

* "Quart. Journ. Geol. Soc.," Vol. XLII. (1886), p. 268; *vide* also "Proc. Cotteswold Nat. F.C.," Vol. VIII. (1886), p. 40.

† "Quart. Journ. Geol. Soc., Vol. XLIX. (1893), p. 127.

On Bredon Hill the Lower Limestone is very finely exposed in the same quarry as that in which the *scissum*-beds are visible. Here the beds are 34 feet 6 inches, thick, and contain numerous fragments of the spines of echinoids. It is in the east face of this quarry that they are best seen, and comprise massive-bedded, yellowish-white, oolitic limestones, becoming flaggy towards the base. The same beds are equally well seen in a still larger quarry a little to the north-west.

The Lower Limestone has been quarried on Hudding-knoll Hill, near Edge, where one bed contains numerous small quartz pebbles, and also pebbles of oolite. It is locally known as the "Dapple-bed."* A *Rhynchonella* occurs in the same stratum. As we have already seen, the Lower Limestone may be well studied on Cooper's Hill.

THE PEA-GRIT.

This term was introduced by the country people on account of the flattened spheroidal masses about the size of a pea which constitute the greater part of the rock where typically developed. According to Prof. Edward Hull, the geographical range of the Pea-grit was very limited. This is correct if the statement referred merely to the typical lithic structure, but it is not so if it meant that where such characteristics were not observable, sediment—contemporaneous with the true Pea-grit—had not been deposited. For example, few would at first sight correlate the rock exposed in the large quarry on Bredon Hill with the pisolite of Cleeve and Crickley, and yet we know by the occurrence of so distinctive a fossil as *Zeilleria circularis* that the deposit at the first locality was laid down contemporaneously with that exposed at the other two.

The pisolitic structure is very interesting. Mr. E. B. Wethered has brought forward evidence to show that the pisolite-spherules are "really formed by

* "Proc. Cotteswold Nat. F.C.," Vol. IX. (1890), pp. 388-392.

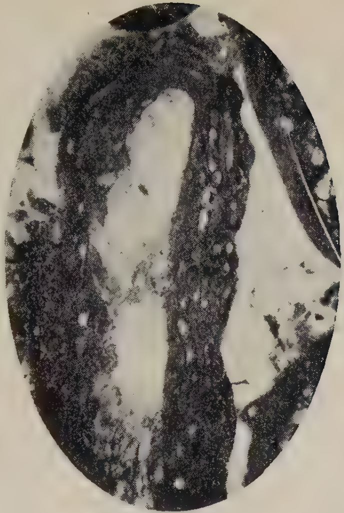
the growth of an organism around a nucleus." This nucleus may be organic or inorganic, whilst according to that author, the surrounding layers of matter in the majority of the pisolites "consist of the tubules of *Girvanella pisolitica*." *Girvanella* was an extremely low form of life. Fig. 1, pl. V., shows *Girvanella pisolitica*. coiling upon itself, with what is suggestive of the primordial chamber at A; whilst figs. 2 and 3 will demonstrate the vermiform nature of the tubuli.* As might be expected, the shape of the pisolite is mainly dependent upon the form of the nucleus. Before Mr. Wethered's investigations it was thought the *Girvanellæ* might have been derived mechanically from the calcareous mud of the sea-bed. This opinion is still held by some geologists.†

Specimens of "sea-mats," which belong to the class Polyzoa (or Bryozoa), are frequently found adhering to the pisolite-spherules, and at Crickley Hill small oysters have been noticed to be attached.

As regards the outliers I have found pieces of typical Pea-grit on Robins' Wood, Oxenton, and Bredon Hills, but on the last-named such fragments are extremely rare. In the quarry on Bredon Hill, which has already been twice referred to (pages 68, 75), the Pea-grit-equivalent, as it occurs in this hill, is well exposed in the west face of the disused portion of the quarry, and *Pseudoglossothyris* (*Terebratula*) *simplex*, *Terebratula plicata*, *Rhynchonella subangulata*, *Rhyn. oolitica*, *Zeilleria circularis*, *Pygaster semisulcatus*, *Diastopora foliacea*, *Spiropora annulosa*, etc., and ossicles of *Pentacrinus*, have been obtained from it. The continuity of the section afforded in the east face of the quarry is affected by a fault, on the south side of which the shelly strata of the Pea-grit-equivalent, together with the Lower Limestone, are inclined at a high angle. In addition to the exposure in the large quarry, the Pea-grit-

* "Geol. Mag.," Dec. III., Vol. VI. (1889), p. 200, Plate VI., figs. 10 and 11.

† "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), "The Lower Oolitic Rocks of England," p. 15.



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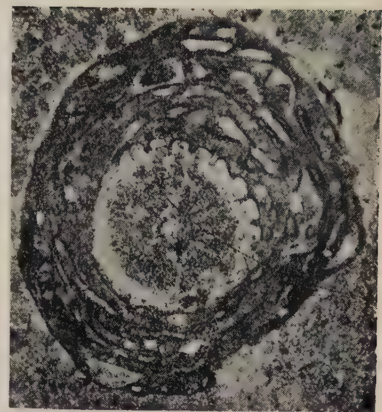

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FIG. 1.—*Girvanella pisolitica*, coiling upon itself. FIG. 2.—*Girvanella pisolitica* shown in section from near the base of the Inferior Oolite, near Cheltenham. × 40 diam. FIG. 3.—Another spherule of *Girvanella pisolitica* from the Pea-grit near Cheltenham. × 30 diam. Shows a joint of crinoid as nucleus. (E. B. Wethered.)

(*Figs. 2, 3, reproduced by permission of the Editor of the Geological Magazine.*)

equivalent—replete with organic remains, chiefly crushed brachiopods—is well exposed in another large quarry about a quarter-of-a-mile to the north-north-west.

In a quarry on Huddingknoll Hill, débris of Pea-grit caps the "Dapple-bed." Several exposures are obtainable near Kimsbury Castle, and in an old excavation on the south side of the lane at Prinknash there is an instructive section. Here a small form of *Rhynchonella* cf. *subangulata* is most abundant, and occurs in a yellowish sandy-looking rock. At Birdlip there is a similar section, but, in addition, it shows the subjacent pisolitic limestones. Birdlip was once a well-known locality to the fossil-collector, but unfortunately, most of the sections are becoming overgrown.*

QUARRY ON THE SUMMIT OF BIRDLIP HILL.

	Ft.	In.
Subsoil		
1. Whitish rubbly rock, flaggy at the base..	2	6
2. Soft, brownish-yellow, rubbly stone; *Zeilleria circularis*, *Zeilleria* cf. *Leckenbyi*, *Pseudoglossothyris* (*Terebratula*) *simplex*, *Terebratula plicata*, *Ter. submaxillata*, *Ter. pisolitica*, *Terebratula* sp., *Rhynchonella Buckmani* (C. Upton, MS.).* *Rhyn. oolitica*, *Rhynchonella subangulata*, *Rhynchonella* sp., and fossils belonging to other classes	3	0
3. Dark-brown, argillaceous deposit, intimately connected with bed 2, and also full of brachiopods	1	2
4. Clayey parting	0	1
5. Hard, light-grey, pisolitic limestone	1	6
6. Bed similar to 5......................	2	1
7. Bed similar to 5......................	0	11

* It was at the "Black Horse," Birdlip, that the Cotteswold Club was founded in 1846.

* Described in a paper read to the Cotteswold Naturalists' Field Club, on March 3rd, 1903, by Mr. C. Upton. *Rhyn. granulata* and *Terebratula degenerata* were also described.

Crossing the Gloucester-Oxford road we come to the far-famed sections at Crickley Hill (Plate VI.). The Pea-grit can, however, be traced from Birdlip Hill along the escarpment, and across the Gloucester-Oxford road, as there are several exposures, apparently unpromising, but it is in such that some of the best specimens of brachiopods have been found. The Pea-grit exposed in the south face of Crickley Hill is richly fossiliferous, the brachiopod *Rhynchonella oolitica* being most abundant, especially a little to the east of the wall which is situated about half-way along the southern scarp. These sections have received considerable attention,* and the locality is noteworthy for the occurrence of a coral-bed on the top of the Pea-grit.† A number of corals have been obtained from this locality, such as *Montlivaltia Wrighti*, *Chorisastræa gregaria*, *Latimæandra Flemingi*, *L. Davidsoni*, *Isastræa tenuistriata*, *Thamnastræa Terquemi*, *T. Mettensis*, etc. Amongst the specimens of echinoids obtained from the Pea-grit here may be mentioned *Cidaris Fowleri*, *C. Bouchardi*, *C. Wrighti*, *Pseudodiadema depressum*, *Hemipedina Bakeri*, *H. perforata*, *H. tetragramma*, *H. Waterhousei*, *H. Bonei*, *Polycyphus normannus*, *P. Deslonchampsi*, *Stomechinus germinans*, *Acrosalenia Lycetti*, *A. spinosa*, *Pygaster semisulcatus*, *P. conoideus*, and *Galeropygus agariciformis;* whilst Mr. W. H. Hudleston has recorded a number of gasteropods. On the north flank of the hill, just round the promontory on which the mass of rock known as the "Devil's Table" is situated, there is a good section of the pisolitic beds yielding, in the upper portion, *Terebratula plicata* somewhat abundantly, and similar rock caps the Lower Limestone in the quarry a few yards further to the east. Pea-grit in a very disturbed con-

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* "Quart. Journ. Geol. Soc.," Vol. XIV. (1858), p. 106; "Proc. Cotteswold Nat. F.C.," Vol. VIII. (1886), p. 43; *Ibid.*, Vol. IX. (1890), p. 289; "A Monograph of the British Jurassic Gasteropoda," Part. I. "Gasteropoda of the Inferior Oolite," Pal. Soc. (1887), p. 67.

† "Proc. Cotteswold Nat. F.C.," Vol. IX. (1890), p. 300; "Geol. Mag.," Dec. II., Vol. V. (1878), pp. 297-305.

CRICKLEY HILL. THE ROCK SEEN IS PEA-GRIT.

(From a photograph by C. Upton.)

dition caps Shurdington Hill, and the ground is strewn with the detached pisolites. Below are hard non-pisolitic beds, belonging, presumably, to the Lower Limestone.

At Leckhampton Hill, débris of Pea-grit occurs in the "Firs-Brake" section, from which the writer obtained a portion of the claw of a crustacean (Pl. XIX., fig. 1). The same beds are also well exposed in the large quarry on Leckhampton Hill. "The best known sections of the Inferior Oolite on the Cotteswold Hills are those at Leckhampton Hill. They have been described by numerous geologists, whose measurements and descriptive details differ to some extent, on account of the varying nature of the beds."* The following is a generalized section of the strata below the Ragstones, as seen in the large quarry† :—

STRATA BELOW THE RAGSTONES AT LECKHAMPTON HILL.

	Ft.	In.
Upper Freestone—		
1. False-bedded oolite, passing down into	25	0
Oolite Marl—		
2. Soft, whitish, crumbly marl, full of brachiopods: lamellibranchs and gasteropods less abundant	10	0
Lower Freestone—		
3. Oolite, false-bedded in upper portion, shelly in lower (stated to be)	130	0
Pea-grit—		
4. Brownish-yellow, rubbly rock, with grey pisolitic bands; *Rhynchonella subangulata, Rhyn. oolitica, Terebratula, Acrosalenia, Pentacrinus, Diastopora, Berenicea,* etc.	12	0
5. Limestone, grey, pisolitic	1	1

* "Mem. Geol. Surv. 'The Jurassic Rocks of Britain,'", Vol. IV. (1894); "The Lower Oolitic Rocks of England," pp. 124, 125.

† "The Cotteswold Hills" (1857), p. 35; "Quart. Journ. Geol. Soc., Vol. VI. (1850), pp. 242 *et seqq.*; "The Geology of England and Wales" (1887), p. 290.

	Ft.	Ins.
6. Limestone, grey, pisolitic ; *Cerithium*	1	5
7. Limestone, grey, pisolitic	1	2
8. Limestone, grey, pisolitic, massive bed	5	6
9. Limestone, several beds............	10	10
Lower Limestone—		
10. Brown and grey limestones	6	0
Scissum-beds—		
11. Ferruginous, sandy beds ; *Rhynchonella cynocephala*, *Aulacothyris Blakei*, etc.	4	0

Beds 9, 10, and 11 are not well exposed now, so that I have quoted the thicknesses assigned to them by Mr. H. B. Woodward. Many of the echinoids noted at Crickley Hill have also been obtained at Leckhampton. The pisolitic beds may be traced along Charlton Common, and have been worked a quarter-of-a-mile south-west of Upper Dowdeswell Manor House.

On the north side of the Chelt valley sections may be seen on the south side of Whittington Wood, near the entrance to Wood Farm ; and again near Woodlands Farm.

In the picturesque quarried face of Cleeve Hill the component beds of the Pea-grit series are admirably exposed. Light-coloured limestones, belonging to the Lower Limestone, are succeeded by the pisolitic beds of the Pea-grit proper, which culminate in the same sort of brownish-yellow rubbly deposit as has been noted at Birdlip and Leckhampton Hills. For becoming acquainted with the succession of the component beds of the Pea-grit series, Cleeve Hill is at the present time the best locality.* Many of the characteristic fossils may be obtained, and frequently portions of the rock are entirely made up of the remains of Polyzoa.

In the north side of the little valley about a quarter-of-a-mile north of Sudeley Park Farm there is a small quarry in which is exposed a bed of typical Pea-grit,

* "Quart. Journ. Geol. Soc.," Vol. XLVII. (1891), pp. 556, 557.

LECKHAMPTON-HILL QUARRY.

(From a photograph by Prof. S. H. Reynolds.)

and it may be from this section that Dr. Wright recorded several echinoids mentioned in his monograph from the locality "Sudely Hill." In Spoonley Wood, however, the Pea-grit-equivalent is a brown arenaceous deposit of considerable thickness. The Pea-grit-equivalent—very similar to that at Bredon Hill—was formerly worked at Brockhampton, and the ventral or pedicle valves of *Pseudoglossothyris* (*Terebratula*) *simplex* have been obtained here, together with *Terebratula plicata* and *Rhynchonella* cf. *subangulata*.

A short distance to the south-east of Dowdeswell Station the main-road passes through a cutting in massive pisolitic beds, but the best section in this area is obtained in the second railway-cutting from Dowdeswell Station, on the line to Chedworth, and is as follows. The thicknesses of the beds and the general details are as recorded by Mr. S. S. Buckman* :—

SECOND CUTTING FROM ANDOVERSFORD.

	Ft.	In.
Lower Freestone—		
1. Whitish freestone		
Pea-grit—		
2. Yellowish-brown, sandy rock, with greyish bands of limestone	23	0
3. Whitish freestone	3	6
4. Hard, shelly limestone, with white, rounded granules, and some larger flattened concretions. *Ludwigia Murchisonæ*, *Pygaster semisulcatus*, *Rhynchonella*; about	20	0

This section is interesting as showing the presence of the same yellowish-brown arenaceous deposit which now has been noticed at Birdlip, Leckhampton, and Cleeve Hills. A new species of *Rhynchonella* is very abundant in the Pea-grit here.

* "Proc. Cotteswold Nat. F.C.," Vol. X. (1892), p. 94.

In the valley of the Churn, above Rendcombe, we find few exposures of this rock; but it is visible in a quarry opposite the turning for Marisden from the Cirencester Road, and in an excavation on the north side of Cowley Wood, near the pond.

In the south-western portion of the district we find Pea-grit near the Cranham Pottery, and again near Knap Farm and Elcombe, in the Slad Valley. In the neighbourhood of Miserden the same rock is visible in the lower of the two excavations near the farm west of Thick Wood; near the "Mill" about half-a-mile east of Miserden; and again just over three-quarters-of-a-mile north-east of Miserden Church. Near here the valley bifurcates, and in the north-westerly extension Pea-grit is seen near the ruined farm known as Moorhouse (Morcombe), where it yields a few *Terebratulæ*. In the valley running northwards past Side is much rubble of typical Pea-grit, and it has been quarried in Park Wood, where it contains *Pseudoglossothyris* (*Terebratula*) *simplex*, *Ter. plicata*, etc.

THE LOWER FREESTONE.

Resting upon the Pea-grit, and in striking contrast to it, is the celebrated Cheltenham building-stone, the geologist distinguishing it by the name of the Lower Freestone. Although of little interest to the fossil-collector, it is of considerable economic value, and the large number of quarries in it bear witness to the truth of this assertion. The fact that it yields few organic remains of any size, is, however, the cause of its utility for building purposes, as it is on that account more readily dressed.

But it must not be thought that the Lower Freestone is absolutely destitute of organic remains, for as the Rev. P. B. Brodie has written: "It is ordinarily termed 'freestone,' and in part forms a fine-grained, light-coloured oolite, closely resembling the Bath freestone, and is nowhere absolutely destitute of organic remains,

the harder stone being made up of comminuted fragments of shells and corals. The more perfect specimens are almost entirely confined to two or more shelly masses . . . . . One of these upper shelly layers may be traced from north to south along the whole of the escarpment and at one spot near the Devil's Chimney, where the freestone is thickest, it shows itself about eighteen feet below the oolite marl, and is there a coarse crystalline rock, mainly composed of shells and corals, a foot and a half thick."*

"On examination it is found to consist of small, round, egg-like grains† cemented together; each grain is formed of a central nucleus, having layers of [carbonate of] lime round it; the nucleus is frequently first enclosed in a soft layer, with a hard layer outside. Occasionally the Oolite is coarse, and the grains large and distinct from each other, but more frequently they are small, and the rock is then more compact. When the grains are very minute, the rock is usually a good limestone, and wears well in buildings. . . In a cubic inch of freestone, in which the granules are of ordinary size, they number not less than 14,000."‡ It may be mentioned, however, that in order to weather really well the stone should be cut into the required shapes as soon after quarrying as possible, or when "green," as after its first dressing the rock "sweats": that is, the water formerly absorbed exudes, and upon evaporation leaves a coating of carbonate of lime over the freshly-cut surface, thus forming a protection against the weather. It will be understood, then, that if this coating be removed, the rock cannot be expected to withstand atmospheric influences to the same extent as when that protective covering is present.

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* "Quart. Journ. Geol. Soc.," Vol. VI. (1850), pp. 240, 241; *vide* also *Ibid.*, Vol. XIV. (1858), pp. 109, 110; and "Proc. Cotteswold Nat. F. C.," Vol. I. (1853), pp. 62-86.

† Hence the origin of the term "Oolite"—Gr. *öon*, egg; *lithos*, stone.

‡ "The Geology of Stroud" (1882), p. 45.

"The block when taken from its bed is generally so soft as to be squared by the saw, but hardens upon exposure, and retains its sharpness for centuries, as is illustrated in the case of Sudeley Castle, and is capable of being delicately moulded. Unless frequently scraped, it soon becomes covered with lichens, which give it a venerable, grayish tint. The presence of this oolite has imparted a peculiar character to the social architecture of the hilly districts as contrasted with that of the plains. Some of the farmsteads, as old as Henry VIII. or Elizabeth, are good specimens of the style of the period, and are built exclusively of stone; while, on the other hand, in the liassic plain, where wood was abundant and stone scarce, we find the same style of architecture modified by the introduction of bricks and wooden framework."*

"Attempts have been made to discover traces of organisms in the nuclei of the oolitic grains, but without success, and the centre is generally of the same construction as the envelope." Since the publication of Witchell's "Geology of Stroud," however, Mr. E. B. Wethered has written of the Lower Freestone: "There is a considerable amount of calcite present, and some of the spherules are granular, without any concentric or other structure. At Bull Cross, near Stroud, the beds appear not to have undergone molecular change to such an extent as at Leckhampton, near Cheltenham; and in my prepared section from these beds I have several spherules showing the structure of *G. pisolitica*."†

At Leckhampton Hill the Lower Freestone has a maximum thickness of 130 feet, but at Uley Bury, near Dursley, it has decreased to about 45 feet. *Pecten* aff. *personatus*, *Terebratula fimbria*, *Rhynchonella* cf. *subangulata*, *Nerinæa*, and ossicles of *Pentacrinus*, occur, but there are no distinctive fossils. By Dr. Lycett the Lower Freestone, Oolite Marl, and Upper Freestone, were described under the denotation, "*Fimbria* Stage." In

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* "Mem. Geol. Surv., 'Geology of the Country around Cheltenham'" (1857), p. 36.

† "Quart. Journ. Geol. Soc." Vol. XLVI. (1890), p. 275.

a quarry arrived at by following the road from Prestbury up Cleeve Hill, past Knoll Hill Farm, until the summit is reached, there is exposed a fossiliferous and somewhat pisolitic bed in the Lower Freestone, yielding the gasteropod *Nerinæa*, and also a *Terebratula* of the *fimbria*-type. As Mr. S. S. Buckman has observed, "certain peculiar characters distinguish it from the *Terebratula fimbria* of the Oolite Marl—it is, in fact, a biologically-earlier fossil, and is the parent of the Oolite Marl shell."

The Lower Freestone may be studied in the large quarries on Scotchquar and Painswick Hills, Birdlip, and, nearer Cheltenham, in the quarries at Leckhampton Hill. The disused quarry to the left of the Cirencester Road a quarter-of-a-mile before reaching the Rifle Range, shows Pea-grit capped by Lower Freestone, the former deposit yielding *Terebratula plicata*, *Terebratula* sp., and *Rhynchonella oolitica*, whilst near the base of the section are fragments of ammonites belonging to the genus *Ludwigia*.

At Whittington the Lower Freestone has been worked by means of adits driven into the hill-side. The bed forming the roof of the main excavation is interesting: it is of conglomeratic nature, and denotes almost contemporaneous erosion. In the flanks of the Postlip Valley are large quarries—the spoil-heaps imparting a rugged look to what otherwise would have been smooth grassy slopes. There are two other sections which may be noticed: the one is in Spoonley Wood, and the other—somewhat difficult to find—in the valley to the south of the road leading from Gloucester to Oxford, about half-way between the "Air Balloon" and the Seven Springs. Both of these sections show the base of the Lower Freestone to be very much bored by annelids; and they are further interesting as showing this "bored-bed," at the former locality resting upon a sandy Pea-grit-equivalent, and at the latter upon typical Pea-grit. Other sections in the Lower Freestone may be noted north of Elcombe, in the Slad Valley; on the hill-side above Sheepscombe; at Cowley; on Yanworth Common; in Pinchley Grove; in

disused quarries east of Chapel Farmcote, and on Bredon Hill. In the Lower Freestone of the Cowley section was observed a *Terebratula* much resembling the species *simplex*. A large quarry on Langley Hill affords the following section :—

QUARRY ON LANGLEY HILL, NEAR WINCHCOMB.

	Ft.	In.
Lower Freestone—		
1. Yellowish-white, oolitic stone, very conspicuously false-bedded ; fragments of *Pentacrinus* ; visible..	33	0
Pea-grit—		
2. Soft, oolitic rock ; ossicles of *Pentacrinus*, Polyzoa, *Pseudoglossothyris* (*Terebratula*) *simplex*	6	0
3. Brownish, rubbly-looking rock ; full of Polyzoa, *Terebratula* sp., *Pseudoglossothyris* (*Terebratula*) *simplex*, *Rhynchonella subangulata* ..	2	2
4. Brownish rock....................	1	4
5. Layer of soft brown marly matter....	0	4
Lower Limestone—		
6. Massive-bedded limestones ; spines of echinoderms, etc. ; visible	3	4
Scissum-beds—		
7. Brown arenaceous beds, massive in places ; *Terebratula euides*, *Rhynchonella subdecorata* (large)		

THE OOLITE MARL AND UPPER FREESTONE.

The Oolite Marl and Upper Freestone next claim attention. For several reasons it is convenient to consider these two subdivisions together. One reason is that in that portion of the district immediately north of Stroud it is often difficult to separate them ; whilst another is, that where the Oolite Marl is exposed, there is often present a capping of Upper Freestone. The

Oolite Marl is, perhaps, the most interesting deposit in the Inferior Oolite Series of the Cotteswold Hills from the brachiopodist's point of view. It is crowded with the shells of which he makes a speciality, and besides being readily extracted, they are usually found in a good state of preservation. And it is not in brachiopods alone that the Oolite Marl is prolific, for the lamellibranchs and gasteropods are also well represented, while in many localities we meet with an abundance of corals. It contains a multitude of minute forms, fragments of crinoids, Ostracoda, etc., known best to him who investigates the deposit under a microscope. Lithically, the Oolite Marl may be described as a yellowish-white, calcareous, argillaceous deposit, somewhat indurated in places. Mr. E. B. Wethered has made the following

ANALYSIS OF THE OOLITE MARL AT LECKHAMPTON.*

Dried at 212° F.

Insoluble residue	3·1
Alumina, with trace of iron	1·7
Carbonate of lime	94·4
Carbonate of magnesia	0·5
Alkalies, by loss	0·3

The Upper Freestone, on the other hand, in the immediate neighbourhood of Cheltenham affords few points of interest, but, as has been already stated, near Stroud it is difficult to separate it from the Oolite Marl, and in the same area it is considerably fossiliferous. Microscopically, the Upper Freestone much resembles the Lower, but in the Chedworth area Mr. Wethered has noticed patches of the rock to be of a blue tint, which he stated was "due to the iron in the rock being in the state of the carbonate—the original condition in which it existed after the formation of the rock." "In the yellow Oolite the iron has been converted into ferric oxide.

* "Quart. Journ. Geol. Soc.," Vol. XLVII. (1891), p. 567, *vide* also p. 562.

Where the original carbonate of iron has not been converted into the ferric condition, the Oolite-spherules show their original structure better than is the case where the iron has been converted into ferric oxide, and in this case the *Girvanella*-tubuli are clearly made out. The tubes show a somewhat dark exterior; and when cut in section the interior is seen to be filled with crystalline calcite or dark argillaceous material. They are smaller than *G. pisolitica* as it occurs in the Pea-grit spherules, but otherwise similar; and I therefore regard them as a variety of that species." In Pl. IV, fig. 3, is represented "a spherule in which tubes are clearly distinguished; but in parts the outlines have been obliterated by mineral changes, and we then get the identical structure which is characteristic of most of the oolitic spherules in the Upper Freestones. There are others which show a regular crystalline concentric arrangement, and they may possibly be of concretionary origin; but I am disposed to regard them as spherules in which the *Girvanella*-tubes have become crystalline, and the outlines consequently obliterated."* Mr. Wethered has met with another form of *Girvanella* in the same rock, to which he gave the varietal name of *Lucei* (fig. 4).

In the extreme south-west portion of the district these subdivisions are exposed in the large quarry on Scotchquar Hill, but they are not separable; while they are again visible on the south-east side of Kimsbury Castle. In Cranham Wood† are several sections of Upper Freestone and one of Oolite Marl. The following section may be constructed by piecing together evidence afforded in the quarry on the south side of the road from Birdlip to Prinknash, and from the quarried face of the hill immediately to the north thereof—on the other side of the road‡ :—

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* "Quart. Journ. Geol. Soc." Vol. XLVI. (1890), p. 276.

† This is marked as Buckholt Wood on the old Ordnance Survey map; but what is there marked Cranham Wood is Buckholt Wood and *vice versa*.

‡ "Quart. Journ. Geol. Soc.," Vol. LIX. (1903), pp. 387, 388.

QUARRY SOUTH OF THE BIRDLIP AND PRINKNASH ROAD.

	Ft.	In.
Upper *Trigonia*-grit—		
1. Grey, shelly rock; *Rhynchonella hampenensis*, *Rhyn. angulina*, *Rhyn.* cf. *subtetrahedra*, *Terebratula globata*,* *Aulacothyris carinata*, *Trigoniæ*, etc.	4	0
Upper Freestone—		
2. Yellowish-white freestone, top-bed slightly bored by annelids and *Lithodomi*; *Terebratula fimbria* noticed at 3 feet 6 inches down, and again at 5 feet 10 inches, being associated at this latter horizon with numerous specimens of *Nerinææ*, also with *Lucina* and *Trigonia*..................	7	10

Crossing to the other side of the road we have in the uppermost excavation—

Upper *Trigonia*-grit—		
1. Rubble with *Terebratula globata*, etc.		
Upper Freestone—		
2. Whitish freestone, top-bed bored; *Terebratula fimbria* at 3 feet 7 in. down	3	8

The section below again shows—

Upper Freestone—		
2. Yellowish-white freestone; about..	7	0
Oolite Marl—		
3. Yellowish-white marl, crowded with *Terebratula fimbria* var., and less so with *Ter. submaxillata*, and *Rhynchonella subobsoleta*; (visible)	1	2

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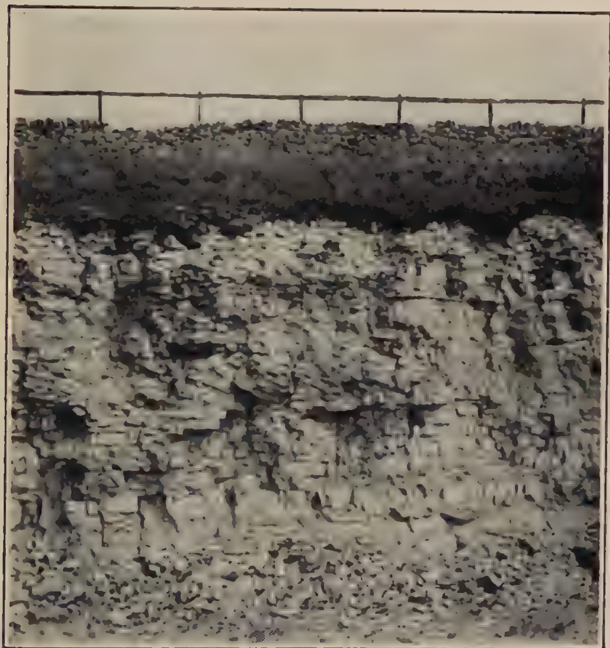
* *Terebratula tumida* was the name given by Davidson to the inflated form which occurs so abundantly in the Upper *Trigonia*-and *Clypeus*-grits; the true *Terebratula globata* being a Fullers' Earth Rock fossil. The mutations of *T. globata* in the Upper *Trigonia*-and *Clypeus*-grits are numerous, and it would be desirable to have noted the exact horizons of the several varieties.

Thus, as shown by the above sections, we have here a thickness of 10 feet 8 inches for the Upper Freestone. It is the uppermost two inches of the Oolite Marl in which the specimens of *Terebratula fimbria* are the most abundant. The majority are not the true *fimbria*, but a variation, the fimbriations being coarse and acute. At the junction of the Prinknash and Stroud roads is an old quarry in which 10 feet 7 inches of much broken-up oolitic freestone is exposed, and on the spoil-heap the writer has found *Terebratula notgroviensis*. On the right-hand side of the road from Birdlip to Foston's Ash, and distant about a mile from the former place, the following section may be studied :—

QUARRY IN CRANHAM WOOD.

	Ft.	In.
Upper *Trigonia*-grit—		
1. Grey, shelly rock ; *Terebratula globata, Rhynchonella angulina, Aulacothyris carinata, Avicula, Limea* etc., separated in places from the Upper Freestone by an earthy deposit	3	0
Upper Freestone—		
2. White, oolitic, shelly freestone, top-bed much bored—especially when the earthy deposit is absent. *Terebratula fimbria*	6	0

A little to the right of the green road leading in the direction of Overtown Farm from near the above-mentioned quarry is another exposure, showing the Upper *Trigonia*-grit—full of shells—resting upon the Upper Freestone. Separating these two deposits, however, is an earthy layer six inches thick, containing badly-preserved specimens of *Terebratula globata* and *Rhynchonella hampenensis*; this intervening deposit belonging to the Upper *Trigonia*-grit. Three furlongs from Birdlip, and to the left of the road to Stroud, is the Buckle-Wood Quarry, near the Saw-mills.



QUARRY IN THE FREESTONE-BEDS NEAR THE "AIR BALLOON," NEAR BIRDLIP. SHOWS FALSE-BEDDING.

(From a photograph by J. W. Gray.)

QUARRY IN BUCKLE WOOD.

	Ft.	In
Upper *Trigonia*-grit—		
1. Grey, very shelly limestone; *Terebratula globata*, *Rhynchonella hampenensis*, *Rhyn. angulina*, *Acanthothyris spinosa*, *Zeilleria Hughesi*, *Pecten demissus*, *Avicula*, *Lima gibbosa*, *Trigonia*, *Ostrea* cf. *acuminata*, etc., about	4	0
Upper Freestone—		
2. White, oolitic freestone. Top-bed almost entirely composed of shell débris and crinoid ossicles. This top-bed is bored a little, but not when there is an earthy deposit immediately above it. This earthy seam often contains some rounded pieces of freestone; (visible)	5	0

Between Birdlip and the "Air Balloon" are many workings in the Freestone-beds. At the eastern end of the south scarp of Crickley Hill, and resting directly upon the Pea-grit, is a white chalky-looking deposit, in places crowded with corals. At first sight this rock might be taken for Oolite Marl, and the occurrence of *Rhynchonella Buckmani*, *Rhyn. granulata*, and *Zeilleria* aff. *Leckenbyi*, with a white chalky matrix, are distinctly misleading. But the relationship of the coral bed (*vide* p. 78) to the Pea-grit can soon be ascertained: the coral-bed rests directly upon it. On Shurdington Hill ("The Crippets,") the strata are very much disturbed, but there is an interesting section where *Rhynchonella Tatei* has been found abundantly. Then there is an old quarry showing the Oolite Marl to the south-west of Ullen Wood, where the gasteropod *Natica* is common, but by far the most important sections are those on Leckhampton Hill, and its easterly continuation, Charlton Common. The

section visible in the Leckhampton Quarry has been already briefly referred to, but it may be mentioned that the marl is somewhat harder here than in the next section to be noticed. On Charlton Common the Upper Freestone and Oolite Marl are easily examined, and although the former rock contains a few fossils, the latter is by far the most prolific. The best exposure is in the hill-side above the "gravel-pit." About two inches above the Lower Freestone at this locality the author was fortunate in finding a specimen of *Pseudoglossothyris galeiformis*—an exceedingly rare brachiopod; and, remarkable to say, it is usually only the ventral (or perforated) valve which is found. The Oolite Marl can also be traced along the north-east side of the hill. At Charlton Common it has yielded *Terebratula fimbria* (three varieties), *Ter. submaxillata*, *Ter. notgroviensis*, *Ter. Whitakeri*, *Zeilleria Leckenbyi*, *Z. Witchelli*, *Pseudoglossothyris* (*Terebratula*) *simplex* (dwarfed form),* *Pseudoglossothyris curvifrons*, *Rhynchonella* aff. *granulata*, *Rhyn. subobsoleta*, *Rhyn. Lycetti*. *Rhyn.* cf. *oolitica*, with *Natica cincta*, *Nerinæa* spp., *Alectryonia* cf. *flabelloides*, *Adelastræa consobrina*, fragments of an ammonite, etc. A thin brownish layer seems almost entirely composed of the minute ossicles of some crinoid. In many places it will be noticed that the Oolite Marl contains bodies much resembling pisolite-spherules. The quarry above Ullen Wood, and visible from the road to Birdlip, near Salterley Grange, shows Oolite Marl and the top of the Lower Freestone. On Wistley Hill is a disused quarry, which affords a section of considerable interest. The Oolite Marl is highly fossiliferous; *Pseudoglossothyris curvifrons* being most abundant. In the harder portions of the Oolite Marl, specimens of *Nerinæa* are not uncommon, together with clusters of *Galeolaria*, of the *socialis*-type. It will be noticed that this deposit is on a level with the Lower *Trigonia*-grit and Snowshill Clay—this being due to a fault (fig. 4).

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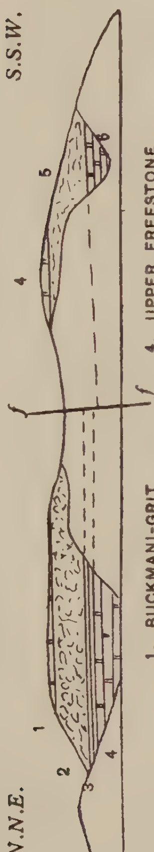
* *Vide* "Quart. Journ. Geol. Soc.," Vol. XIV. (1858), p. 108.

Fig. 4.—Section on Wistley Hill.



1. Buckmani-Grit
2. Lower Trigonia-Grit
3. Snowshill Clay
4. Upper Freestone
5 Oolite Marl
6. Lower Freestone

ff. Fault.

[Scale—Vertical & Horizontal, 1″ = 48 ft.]

On the Cleeve Hill plateau there are two sections to which attention may be directed in connection with these beds. The first is a quarry about the middle of the western face of Cleeve Hill. Here *Zeilleria Witchelli* is the most abundant fossil. The other section is above Cotehay Farm, in the Charlton Abbots Valley. Here there is evidence of a sand deposit (Harford Sands); Oolite Marl with *Terebratula fimbria*, *Ter. submaxillata*, and *Rhynchonella subobsoleta*; Lower Freestone; Pea-grit [a thin bed with imperfect specimens of *Pseudoglossothyris* (*Terebratula*) *simplex*]; and unfossiliferous limestones: the last belonging, presumably, to the lower portion of the Pea-grit equivalent and the Lower Limestone.

About a quarter-of-a-mile to the north-east of Sudeley Park Farm we get another sight of the Oolite Marl. A section in the north side of the road three-quarters-of-a-mile east of Withington Church, leading over the hill to Compton Abdale, shows the succession from the Oolite Marl to the Upper *Trigonia*-grit, but I have refrained from assigning thicknesses, as the strata are very much disturbed, and, accordingly, measurements would be of little value.

ROAD-SECTION THREE-QUARTERS-OF-A-MILE EAST OF WITHINGTON CHURCH.

	Ft.	In.
Upper *Trigonia*-grit—		
1. Grey, shelly stone; *Terebratula globata*, *Rhynchonella*, etc.		
Notgrove Freestone—		
2. White, oolitic freestone, top-bed bored.		
Gryphite-grit—		
3. Greyish-brown stone; specimens of *Gryphæa* very abundant.		
Buckmani-grit—		
4. Greyish-brown, sandy stone; *Gryphæa*, *Modiola Sowerbyana*, *Hinnites abjectus*, *Lima*, etc.		
5. Bluish-grey, clayey band, shell fragments		

	Ft.	In.
6. Greyish-brown, sandy stone: *Terebratula Buckmani*, *Myacites*, *Galeolaria socialis*		
Lower *Trigonia*-grit—		
7. Slightly ironshot stone and marl; *Myacites*, *Ostrea*, *Trigonia*, etc. ..		
Snowshill Clay—		
8. Tough blue and yellowish clay; fills up some of the upper joints in the Upper Freestone		
Upper Freestone—		
9. Yellowish-white, oolitic freestone; *Rhynchonella Tatei*: passing into		
Oolite Marl—		
10. Soft, yellowish marl; *Rhynchonella subobsoleta*, *Terebratula fimbria*, *Lucina*, etc.		

In Pinchley Grove the Upper Freestone and Oolite Marl are to be seen, the thickness which has been assigned to the former deposit being 16 feet 6 inches, and to the latter 5 feet 6 inches. On the hill-side south of Upper Coberley, and again about a mile north-west of Colesbourne, are good sections of the Oolite Marl, yielding *Terebratula fimbria*, *Ter. submaxillata*, *Rhynchonella subobsoleta*, and *Pholadomya*; and at the latter locality specimens of *Nerinæa* are very abundant.

In the neighbourhood of Brimpsfield are several quarries showing the Upper *Trigonia*-grit resting directly upon the Upper Freestone; but the surface of the latter is not extensively bored, as is the case on Bull Bank Common, where it is simply riddled. The exact position of the Bull-Bank section is on the right-hand side of the road from Miserden to Duntisborne (Duntshorn) Abbotts, where it climbs the east side of the Common.

In the Slad Valley are several sections. In the quarry on Swift's Hill, a deposit about 4 feet 6 inches thick, the equivalent of the Upper Freestone and Oolite Marl, is exposed, containing *Terebratula fimbria* and *Rhynchonella Tatei*; whilst a

quarter-of-a-mile to the north the same beds are seen in the south bank of the lane leading up the hill to Cats Wood. *Terebratula fimbria* is the most abundant fossil here, the best specimens being procured from the harder masses of marl. In the deposits of the hemera *bradfordensis* at Swift's Hill, gasteropods are abundant. On the north-west face of the hill to the north of the locality marked as Piedmont on the Geological Survey Map, are similar exposures. One of the most interesting sections in the Cotteswold country is that afforded in a large quarry near Wick Street, distant about three-quarters-of-a-mile from Painswick, in a southerly direction. Here the Upper Freestone and Oolite Marl are not separable, for the latter comprises beds of pale earthy and whitish oolitic limestone, graduating upwards into the Upper Freestone, which presents somewhat similar lithic characters. In almost the highest beds, *Rhynchonella cynomorpha*—a shell somewhat like a small *Rhynchonella cynocephala*—abounds. The other fossils which may be procured from these beds here are *Rhychonella Tatei*, *Rhyn. subobsoleta*, *Terebratula submaxillata*, *Ter. fimbria*, *Zeilleria Leckenbyi* (rare), *Pholadomya*, *Natica*, *Lucina*, etc. A species of *Reynesella* has been obtained from this quarry by Mr. E. T. Paris.

In a quarry a little under half-a-mile east of Loveday's Mill the Oolite Marl and a freestone deposit are exposed in a quarry, the former rock yielding corals abundantly. "From the number of corals in these beds it was many years ago suggested by the Rev. P. B. Brodie that the formation is the result of the disintegration and partial decomposition of a coral reef,—a suggestion which has since found general acceptance, and which, from the broken condition of the corals and the abundance of long spiral shells of the genera, Nerinæa and Chemnitzia, whose favourite habitat is in coral formations, appears to be justified. The reef probably had its southern limit near Stroud, and extended over the northern Cotteswolds and far into the valley of the Severn."*

* "The Geology of Stroud" (1882), pp. 50, 51.

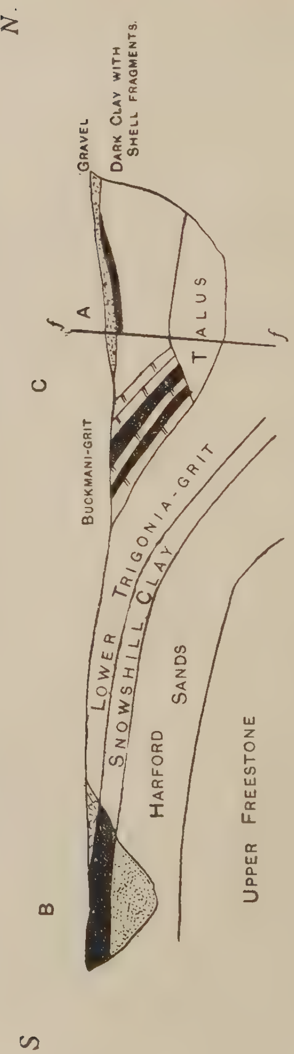
It is not necessary to go far in order to study these deposits, for the exposures on Leckhampton Hill and Charlton Common are distinctly typical.

THE HARFORD SANDS.

These sands were named on account of their development around Harford, near Bourton-on-the-Water, but in the district under review they occur only on the Cleeve Hill plateau and in the neighbourhood of Farmcote Wood. The reason for their limited geographical distribution will be given when dealing with the historical geology of the epoch. On Cleeve Hill they are well exposed near the "Roadstone Hole"—or the series of quarries about 450 yards north-east of the well-known ancient camp. The deposit consists of white and pale-brown sand, often cemented together by carbonate of lime. The rain-water gradually dissolves this calcareous cement, and leaves an incoherent accumulation of sand, composed of very fine quartz grains. The mode of disintegration often causes phenomena similar to those of a nodule-shaped mass of rock embedded in sand. Such appearances have given rise to the view that Cleeve Cloud was submerged in the Glacial Epoch: the nodule-shaped sandstone masses having been mistaken for "Northern Drift" boulders!

Now this section near the "Roadstone Hole" is important, as it was here that the "Northern Drift" boulder was obtained. But under the turf, and capping the thin clay deposit which occurs immediately above the Harford Sands, is the Lower *Trigonia*-grit. A glance at Table III. will show the position the Lower *Trigonia*-grit occupies in the Inferior Oolite Series, and as we have here, in ascending order, the Harford Sands, Snowshill Clay (*i.e.*, the clay deposit), and Lower *Trigonia*-grit, it follows that, instead of the so-called boulder having been left in the Glacial Epoch, it is merely the product of the weathering of a sandstone bed of the hemera *concavi* (fig. 5).

Fig. 5.—Section across the "Roadstone Hole," Cleeve Hill.



(Scale—Vertical and Horizontal, 1"=24ft.)

In the excavation B the following sequence may be noted :—

	Ft.	Ins.
Lower *Trigonia*-grit—		
1. Slightly ironshot stone, bluish-grey and brownish ; *Aulacothyris Meriani*, *Terebratula* sp., *Rhynchonella* sp., *Chorisastræa*, *Epismilia sp ? Pholadomya fidicula* : (visible just below the turf on the east side of the opening)		
Snowshill Clay—		
2. Greyish and purple marl............	0	3
3. Very stiff, bluish-grey clay..........	0	6
4. Brown clay, enclosing grey stone band two inches thick; black streaks near base	0	9
Harford Sands—		
5. Sandstone, greyish-yellow, calcareous, *Rhynchonella*, *Ctenostreon*, *Trigonia*	1	8
6. Sand, pale-yellow, fine, weathers white ; (visible)................	4	0

Looking northwards across the valley, the growth of gorse-bushes indicates the presence of the Harford Sands. Immediately above the Sands can be seen shallow excavations, and, upon closer inspection, large masses of the top-bed of the Harford Sands will be noticed lying about. The gorse-bushes are useful in indicating the presence of this sand deposit, and Mr. S. S. Buckman has it on good authority that it used to be extensively dug and sent to Staffordshire on the backs of donkeys, for use in the potteries. The deposit has been noticed a-mile-and-three-quarters east-south-east of Winchcomb Church, on Sudeley Hill, where it is stated to yield many lamellibranchs ; and again on the hill above Prestbury.

THE SNOWSHILL CLAY.

Resting upon the Harford Sands, in the excavation near the "Roadstone Hole," we saw that there was an argillaceous deposit—a stiff bluish-grey and brown clay—known as the Snowshill Clay, on account of its development between Snowshill and Broadway, in the North Cotteswolds. In the section near the "Roadstone Hole" it is about a-foot-and-a-half thick. On the opposite side of the valley, in the excavations referred to when dealing with the Harford Sands, the Snowshill Clay is clearly exposed, and formerly its relationship to the subjacent sand was visible. Immediately above is the Lower *Trigonia*-grit, and it is noticeable that a similar coral-bed is present here to that of which the writer found indications in the opening near the "Roadstone Hole." In the neighbourhood of Painswick the Snowshill Clay is absent, and it is not until we arrive at Leckhampton Hill that it is seen in places separating the Upper Freestone from the Lower *Trigonia*-grit: not the Upper Freestone from the Harford Sands, be it noted. On Charlton Common the thickness has increased to 1 foot 6 inches; this measurement having been obtained in the quarry which is reached by following the road from Southfield Farm upwards to near the top of the Common, but turning to the right into the first disused quarry—in fact the only one on that side of the road. Here we have the Upper Freestone exposed, and immediately above it, and just below the turf, is the sought-for deposit containing a few shell fragments—mostly of *Ostreæ* derived from the surface of the subjacent freestone, and a few fragments of a *Terebratala* of a *submaxillata*-type.

The same deposit has been observed in the old quarry on Wistley Hill, where, according to Mr. Buckman, it is as much as 2 feet 7 inches in thickness. In the quarry on Ravensgate Hill it is only 7 inches thick.

At Rowell (or Roel) Gate there is a disused quarry which has been excavated in the Lower *Trigonia*-grit, but below that rock is a very fair exposure of Snowshill Clay. In the road-section three-quarters-of-a-mile east of

Withington Church the clay is very clearly exposed, being about 5 inches thick—the uppermost inch of a yellow tint, the rest blue. It has also been noticed, as a bed 10 inches thick, in the eighth cutting from Andoversford towards Chedworth.

THE LOWER *TRIGONIA*-GRIT.

Lithically, the Lower *Trigonia*-grit, which was laid down during the hemera *discitæ*, may be described as a slightly ironshot shelly stone, somewhat crumbly, with a few layers of brown marl. Lamellibranchs are very numerous, and at a certain horizon a species of *Aulacothyris* is abundant. The Lower *Trigonia*-grit has been opened up in shallow quarries on the summit of Scotesquar Hill,* but it is not until we arrive at Cuckoo Pen, 2½ furlongs from Birdlip, on the right-hand side of the road to Cheltenham, that there is a good exposure.

Cuckoo Pen Quarry.

	Ft.	Ins.
Upper *Trigonia*-grit—		
1. Grey, shelly stone ; *Terebratula globata*, *Rhynchonella hampenensis*, *Acanthothyris spinosa*, *Trigonia*, *Avicula digitata*, etc.	2	0
Lower *Trigonia*-grit—		
2. Rubbly ironshot stone, top portion slightly bored ; *Gryphæa*, *Lima*, *Serpula*	3	2
Upper Freestone—		
3. White, oolitic freestone ; *Echinobrissus*	7	0

About three-quarters-of-a-mile further on a quarry will be noticed on the same side of the road as the above. The beds are disturbed by a small fault, having a throw of 2 feet 9 inches.

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* Spelt in various ways, but "Scotesquar" appears to be the correct name. Referred to on pages 85, 88, as "Scotchquar."

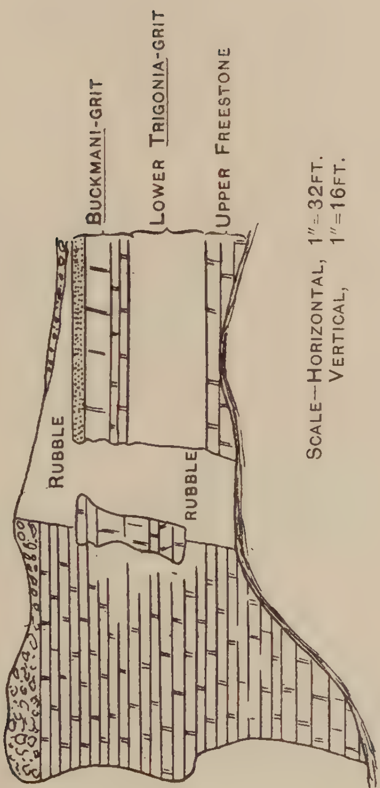
QUARRY NEAR THE "AIR BALLOON," ON THE EAST SIDE OF THE ROAD.

	Ft.	Ins.
Buckmani-grit—		
1. Grey, sandy, shelly stone		
2. Yellow, incoherent sands, with a layer of stone near base		
3. Blue and brown, clayey shale; *Terebratula Buckmani*, *Ter. crickleyensis*	0	6
4. Grey, sandy stone, embedded in nodular masses in a sandy marl; thickness very variable, 4 to 10 inches	0	7
5. Grey, sandy stone, several beds; *Acanthothyris* sp., *Modiola*	1	8
Lower *Trigonia*-grit—		
6. Slightly ironshot, rubbly, marly stone, *Gryphæa*, *Pholadomya*	3	2
7. Earthy layer; *Rhynchonella*, *Aulacothyris Meriani*	0	4
Upper Freestone—		
8. Whitish, oolitic freestone	9	6

On the other side, or west side, of the road is Tuffley's Quarry. This section will be noticed in detail when dealing with the *Buckmani*-grit (page 110). The Lower *Trigonia*-grit, 3 feet 10 inches thick, is seen resting upon the Upper Freestone, whilst the characteristic brachiopod occurs on the spoil-heap, its exact horiozn being 8 inches above the latter rock. As we shall see shortly, this record of *Aulacothyris Meriani* here is important.

At Leckhampton Hill the deposit may be observed at the top of the large quarry. The lower part is markedly conglomeratic, but as we proceed towards Charlton Common the Snowshill Clay makes its appearance, and the conglomerate is then, of course, absent. The appended diagram will show the position of the Lower *Trigonia*-grit here, and also the fault by which the beds are affected (fig. 6).

Fig. 6.—Section at Leckhampton Hill.



The section of the Ragstone-beds here is as follows :—

	Ft.	Ins.
Buckmani-grit—		
1. Rubble of yellow sandy rock; *Gryphæa, Modiola, Terebratula Buckmani*		
2. Fine yellow sand; *Terebratula Buckmani, Ter. crickleyensis*	0	8
3. Yellowish-brown limestone, massive-bedded; *Terebratula Buckmani* ..	3	1
Lower *Trigonia*-grit—		
4. Yellowish-brown and grey, ironshot, rubbly limestone, conglomeratic near the base; *Gresslya abducta, Myacites, Gryphæa, Trigonia formosa, Terebratula degenerata, Aulacothyris Meriani, Modiola Sowerbyana, Phyllogyra Etheridgei,* etc.	7	0
5. Earthy layer, with rolled pieces of rock	0	4
Upper Freestone—		
6. Whitish oolitic freestone		

A little to the west the Ragstone-beds are much better shown.* The best sections of the deposit, however, are on Charlton Common. In an old excavation, a few yards to the east of the place where the Snowshill Clay was observed, the *Aulacothyris-Meriani*-horizon is 2 feet 10 inches above the Upper Freestone, and along this line the brachiopod is most abundant, being in association with a *Terebratula* of the *cortonensis*-type and a *Rhynchonella*. In this section the rock above the *Meriani*-bed also belongs to the Lower *Trigonia*-grit, and is prolific in lamellibranchs, such as *Opis Myacites, Pholadomya, Modiola, Gryphæa*, etc. The same deposit, 6 feet 4 inches thick, is visible in the disused quarry on Wistley Hill, and *Aulacothyris Meriani* has been found. Here there are indications of a coral-bed, that known as the

* "Quart. Journ. Geol. Soc.," Vol. XLIX. (1893), p. 512.

"Second Coral-bed:" the "Third Coral-bed" being in the Oolite Marl, and the fourth directly upon the Pea-grit.

On the eastern flank of Ravensgate Hill, just outside Lineover Wood, is another disused quarry, in which, at the present time (1903), the following beds may be studied:—

Quarry on Ravensgate Hill.

	Ft.	Ins.
Buckmani-grit—		
1. Grey, sandy stone; *Terebratula Buckmani, Galeolaria socialis, Pecten, Gryphæa, Trigonia*	2	0
Lower *Trigonia*-grit—		
2. Rubbly stone and marl	1	6
3. Slightly ironshot stone	4	6
4. Marly stone	0	4
5. Yellowish marl, with *Aulacothyris Meriani*	0	3
6. Grey ragstone; *Gresslya abducta*	1	8
7. Marly stone; corals, *Heterastræa* sp. nov., *Isastræa tenuistriata;* Polyzoa	1	2
Snowshill Clay—		
8. Blue clay	0	5
9. Yellow clay	0	2
Upper Freestone—		
10. Whitish oolitic freestone, pink bed at the top	13	0

On the Cleeve Hill plateau the Lower *Trigonia*-grit, as already recorded, is exposed in an opening near the "Roadstone Hole," and in that quarry itself. Here the deposit has yielded *Modiola Sowerbyana* (Pl. XVIII., fig. 6), *Modiola imbricata, Gervillia tortuosa, Cœlastarte excavata, Ceromya bajociana, Lima bellula, Pecten* spp., *Pholadomya fidicula, P.* cf. *Heraulti, Ostrea, Trigonia striata? Cucullæa oblonga, Goniomya, Trigonia costata, Opis* cf. *cordiformis,*

Belemnites sp., and ammonites. Several good corals have been obtained from it here; such as *Chorisastræa* (*Thecosmilia*) *gregaria* and *Montlivaltia*. On the opposite side of the valley—in the same excavations as those in which the Snowshill Clay is exposed—corals are most abundant, the other fossils procurable being *Pholadomya fidicula*, *Pholadomya* cf. *Heraulti*, *Modiola Sowerbyana*, *Trigonia formosa*, *Myacites jurassi*, *Myacites tenuistriatus*, *Goniomya*, *Alectryonia* sp., *Alectryonia flabelloides*, *Gryphæa*, *Pecten* sp., *Astarte elegans*, *Galeolaria socialis*, *Pleurotomaria*, *Pseudomelania*. An old excavation at the south-eastern end of the Race-course may be mentioned as a good place for several species of *Trigonia*. Other localities where this subdivision may be studied are: at the base of the quarry on Sudeley Hill; near Rowell Gate; and in the road-cutting three-quarters-of-a-mile east of Withington Church.

In the Painswick area there are two excellent sections, the one at the Frith Quarry, and the other in the large quarry on Swift's Hill. The latter section is situated on the hill-side overlooking Knap Farm, and to the east thereof. In it are shown 5 feet 4 inches of the rock under consideration, the bottom layer of which—a yellowish marl—encloses pebbles of a whitish rock, presumably Upper Freestone. At the Frith Quarry the Lower *Trigonia*-grit is about 5 feet 6 inches thick, the uppermost bed being crowded with lamellibranchs, amongst which may be noted: *Trigonia formosa*, *T. costata*, *Opis trigonalis ?*, *Cucullæa*, *Myacites*, *Pholadomya*, *Ostrea*, *Ceromya*, *Gryphæa*, etc. The deposit here has yielded several examples of a *Terebratula*, for which Mr. C. Upton has proposed the specific name of *degenerata*.* The writer has obtained this fossil from the equivalent deposit at Leckhampton Hill and Charlton Common.

When fossils are obtained from the spoil-heaps of quarries in the Ragstone-beds it is often possible to discover which came from the Lower *Trigonia*-grit on account of their slightly ironshot matrix.

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* See page 77.

THE *BUCKMANI*-GRIT.

Sandy ragstones, with a deposit of sand and a marked clay band, constitute what is known as the *Buckmani*-grit. The distinctive brachiopod *Terebratula Buckmani* occurs mainly in the clay and sand deposits, the other fossils of this class being *Terebratula Uptoni*, *Ter. crickleyensis*, and an *Acanthothyris*. The *Terebratulæ* are peculiar to this subdivision, which has been dated as post-*discitæ*. The layers of sand and clay are the best guides to the rocks under consideration, being readily recognised. On Scotesquar Hill they are seen in the shallow quarries on the summit, and the beds are again visible on Kimsbury Castle. In Buckholt Wood the *Buckmani*-grit is exposed for a thickness of 14 feet 4 inches.

Quarry in Buckholt Wood.

	Ft.	Ins.
Upper *Trigonia*-grit—		
1. Grey, shelly ragstone, with earthy layer at base	1	8
Gryphite-grit—		
2. Greyish-green, sandy rock, slightly bored by *Lithodomi* and annelids; small *Gryphææ*, small smooth Pectens abundant near the top ..	3	2
Buckmani-grit—		
3. Sandy stone; *Terebratula Buckmani*	7	0
4. Sandy parting, stone in places	0	4
5. Hard, grey, sandy rock; *Gryphæa*, *Modiola*, *Terebratula Buckmani*, *Ter. Uptoni*; and a biplicate *Terebratula* found loose is assigned to this horizon by Mr. Buckman	1	10
6. Yellow, incoherent sand, of variable thickness, owing to irregularity of under and upper surface of super- and sub-jacent beds respectively	1	8
7. Bed similar to 5	1	0

	Ft.	Ins.
8. Yellowish brown sand at top, greyish and marly below	1	3
9. Pinkish-grey sand rock	1	3
Lower *Trigonia*-grit— (?)		
10. A deposit obscured by fallen débris is assigned with a query by Mr. Buckman to this subdivision	2	6

This reading differs from that given by Mr. Buckman in his paper on "The Bajocian of the Mid-Cotteswolds" as regards the thickness assigned to bed 3: in the paper referred to this bed is stated to be only 4 feet thick.

On the north-east flank of Cooper's Hill a small section—reached by following the path from the road to Prinknash where it turns the corner near the house in Buckholt Wood—shows the shelly beds of the Upper *Trigonia*-grit, full of *Rhynchonella hampenensis* and *Terebratula globata*, and 4 feet 3 inches thick, separated by a thin earthy layer—in which *Rhynchonella hampenensis* was observed—from the *Buckmani*-grit, the top-bed of which is 1 foot 2 inches thick, and is bored. This bed rests upon a yellowish sandy stratum, visible for a thickness of three inches. On the north-west side of the hill the "bored-bed" of the *Buckmani*-grit is exposed in an old quarry capped by the Upper *Trigonia*-grit, the latter rock yielding some good specimens of *Trigonia costata* When this quarry was worked, many specimens of *Terebratula crickleyensis* and *Ter. Buckmani* were obtained. In Buckholt Wood, on the north side of the road, a short distance to the east of the corner referred to, the Upper *Trigonia*-grit is exposed, resting upon what would appear to be the basement-bed of the *Buckmani*-grit. A quarry known as Dunley—situated to the right of the by-road from Foston's Ash to Cranham Common, where this meets the by-lane which leaves the Stroud and Birdlip road just before Hazel Hanger Wood—affords a good section of the beds under review.

Dunley Quarry.

	Ft.	Ins.
Clypeus-grit—		
1. White, oolitic stone, much broken up	2	0
Upper *Trigonia*-grit—		
2. Grey, shelly stone; *Terebratula globata*, *Zeilleria Hughesi*, *Aulacothyris carinata*, *Rhynchonella* spp.		
Buckmani-grit—	4	0
3. Grey and pinkish sandy stone, in two beds; *Pecten*, *Ctenostreon pectiniforme* or *proboscideum*. Very much bored	2	6
4. Grey, sandy parting; *Terebratula Buckmani*	0	3
5. Brownish, sandy stone: 10 inches to 1 foot 4 inches	0	11
6. Greyish, sandy, shaly deposit; *Terebratula Uptoni*, *Ter. Buckmani*, and a biplicate *Terebratula*......		

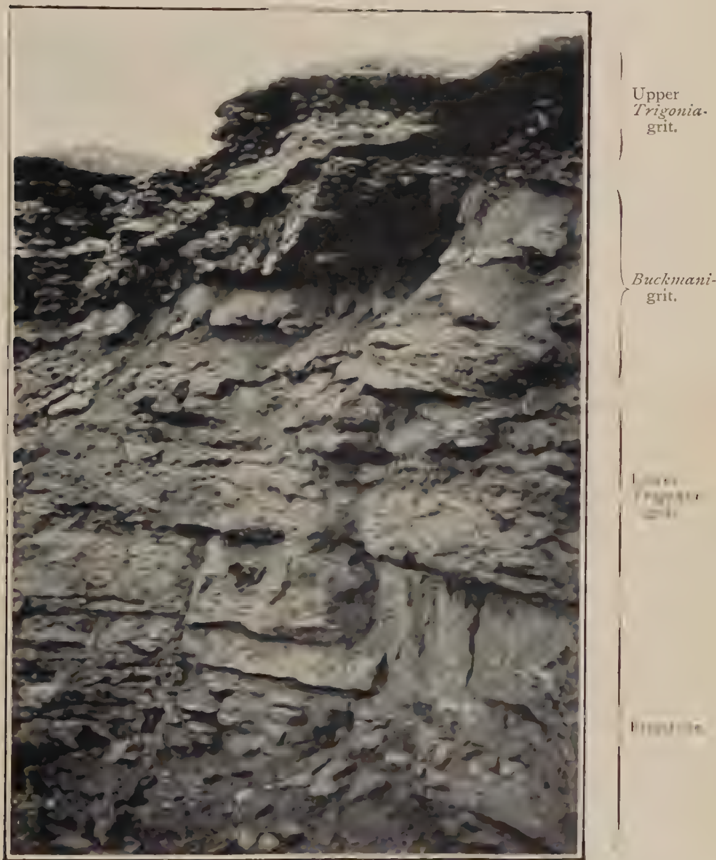
The lowest deposit mentioned above rests upon a most uneven surface of the underlying sandy limestone. As it forms the floor of the quarry (1903), the contained brachiopods are easily obtained. Attention may be drawn to the horizon of the biplicate *Terebratula*. In no section in the Cotteswolds have I noticed the bed immediately below the Upper *Trigonia*-grit so conspicuously bored by annelids.

A little over a quarter-of-a-mile to the north-east of Dunley the Upper *Trigonia*-grit rests directly upon the Upper Freestone, and it is not until Birdlip has been passed that the *Buckmani*-grit is again seen in quarries on either side of the road, just before reaching the "Air Balloon." That on the east side of the road has already been described; that on the west is known as Tuffley's Quarry (Plate IX).

TUFFLEY'S QUARRY, BY THE "AIR BALLOON."

	Ft.	Ins.
Upper *Trigonia*-grit—		
1. Grey, shelly stone; *Rhynchonella angulina*, *Rhyn. hampenensis*, *Zeilleria Hughesi*, *Acanthothyris spinosa*, *Pecten demissus*, *Avicula*, *Limea*. etc.	4	0
Buckmani-grit—		
2. Grey, sandy ragstone; slightly bored by annelids and *Lithodomi*; *Isocardia cordata*, *Terebratula Buckmani*	1	8
3. Conspicuous deposit of bright-yellow sand	1	7
4. Bluish-grey and brown, stiff clayey deposit; *Terebratula Buckmani*, *Ter. crickleyensis*, *Acanthothyris*..	0	6
5. Grey, sandy marl, containing in places nodule-shaped masses, and where soft *Terebratula Buckmani* may be easily extracted; 3 inches to 10 inches	0	10
6. Hard, pinkish-grey stone; *Galeolaria socialis* abundant, lamellibranchs	1	9
Lower *Trigonia*-grit—		
7. Slightly ironshot, marly, rubbly stone, *Aulacothyris Meriani*, *Serpula* spp. *Myacites*, *Modiola Sowerbyana*, etc.	3	6
8. Earthy layer, with a few pebbles	0	4
Upper Freestone—		
9. Whitish, oolitic limestone; (visible)..	10	3

On Shurdington Hill the writer has collected *Terebratula Buckmani*, but the beds cannot be seen *in situ*. The sand and clay beds of the *Buckmani*-grit are visible near the place where the fault depicted in fig. 6 dislocates the strata at the top of the large quarry on Leckhampton



TUFFLEY'S QUARRY NEAR THE "AIR BALLOON," NEAR BIRDLIP.

(From a photograph by J. W. Gray.)

Hill, but being somewhat inaccessible it is best to search the talus-heap immediately below, for by so doing it is possible that examples of *Terebratula Buckmani* and *Ter. crickleyensis* may be collected. On Charlton Common the *Buckmani*-grit may be studied in the quarry at the top of the road leading to the summit. Here, six massive beds, with a total thickness of 7 feet 8 inches, are seen above the sand-bed. At 6 feet, and again at 6 feet 7 inches and 7 feet 8 inches above the sand-bed, *Terebratula Uptoni* may be obtained.

Above the village of Whittington is a quarry in which the *Buckmani*-grit has been reached, for numerous examples of *Terebratula Uptoni* have been found on the spoil-heaps. This deposit is also worked for road-metal at the "Roadstone Hole." On the spoil-heap are found small specimens of *Terebratula Buckmani;* also *Ter. Uptoni*, and an *Acanthothyris*. In a mass of sandy rock immediately overlying a clayey, but much disturbed, bed below the spot marked A in fig. 5, the writer has obtained the characteristic brachiopod *Terebratula Buckmani*; whilst in the easternmost excavation several *Terebratulæ* of the same biplicate form as those procured at Dunley were found in association with *Terebratula Uptoni*.

The quarry on Sudeley Hill shows about 10 feet of this deposit, yielding *Terebratula Uptoni* and *Terebratula Buckmani*. The following section is based upon that recorded by Mr. Buckman :—*

SUDELEY HILL.

	Ft.	Ins.
Notgrove Freestone—		
1. Fragments in the soil		
Gryphite-grit—		
2. Yellowish marl and stone; broken fragments of *Gryphæa*	1	6

* "Quart. Journ. Geol. Soc.," Vol. LVII. (1901), p. 121.

	Ft.	Ins.
3. Shelly ragstone, with numerous *Gryphææ;* and with *Belemnites (Pachyteuthis) gingensis* near the top	2	0
Buckmani-grit—		
4. Yellowish, sandy stone, with *Trigonia* sp. and *Modiola* sp.; *Terebratula Uptoni* 3 feet down; *T. Buckmani*, single, 4 feet 6 inches down. The top of this series is a somewhat hard, projecting bed. Visible	8	0
Add perhaps	2	0
Lower *Trigonia*-grit—		
5. Hard, brown-speckled, somewhat sandy stone. *Ostrea;* smooth *Pecten;* very large *Cucullæa.* Lower $2\frac{1}{2}$ feet visible in the quarry at a waggon-loading ledge. Possible thickness	7	0

The *Buckmani*-grit is exposed in the road-cutting three-quarters-of-a-mile east of Withington Church; and again on Yanworth Common, where *Terebratula Uptoni* is not uncommon. The other fossils obtainable at the latter locality are *Terebratula Buckmani*, *Pholadomya fidicula*, *Pholadomya* sp., *Gryphæa* cf. "*sublobata*," *Modiola Sowerbyana*, and *Chorisastræa* sp.

Coming to the valley of the Churn, the *Buckmani*-grit, with the top-bed bored, is exposed in a quarry to the north of the Cirencester Road, near Hill Barn, Upper Coberley (or Cubberley). At the north-west corner of Cowley Wood there is the following section:—*

QUARRY NEAR COWLEY WOOD.

	Ft.	Ins.
Clypeus-grit—		
1. Yellowish, rubbly stone, pisolite-spherules; *Clypeus Ploti*, *Terebratula globata*, *Terebratula* sp., *Pholadomya*, *Pleurotomaria*, etc...	3	0

* "Quart. Journ. Geol. Soc.," Vol. LIX. (1903), p. 383.

	Ft.	Ins.
2. Greyish-yellow limestone; very few fossils	1	1
Upper *Trigonia*-grit—		
3. Greyish, shelly limestone, lowest stratum bluish-grey, massive-bedded; *Terebratula globata*, *Rhynchonella hampenensis*, *Rhyn. angulina*, *Zeilleria Hughesi*, *Acanthothyris spinosa*, *Trigonia*, *Avicula*, *Lima*, *Ostrea*, *Holectypus*, etc.	8	8
Buckmani-grit—		
4. Greyish, arenaceous, clayey, shale; *Terebratula Buckmani*, *Terebratula crickleyensis*, *Acanthothyris* sp. ..	0	0-4
5. Hard, grey, sandy limestone, very much bored by *Lithodomi*, less so by annelids; *Terebratula Buckmani*, *Galeolaria socialis*, *Trigonia formosa*, *Gervillia*, *Lima*, etc.	1	5

This section presents several points of interest. Bed 4 is often absent, but when present rests upon an exceedingly irregular surface of the subjacent limestone. This latter bed, when 4 is wanting, is found to be very much bored—especially by *Lithodomi*. The top-bed of the Upper *Trigonia*-grit is covered with *Ostreæ*, and occasionally it is bored by *Lithodomi*: an interesting feature, as it indicates a slight erosion. The beds in this quarry are affected by a fault; on one side they dip slightly to the south-east, on the other the inclination is more pronounced to the north-west.

By the side of the road on Longridge, near Painswick, there are several openings in which the *Buckmani*-grit has been worked.

The most important section in this area is at the Frith Quarry, on Juniper Hill, of which the following is the record by Mr. Buckman :—*

* "Quart. Journ. Geol. Soc., Vol. LI. (1895), pp. 399-400. *Vide* also C. Upton in "The Stroud Valley Illustrated" (1902), p. 68.

SECTION OF THE RAGSTONES, FRITH QUARRY.

	Ft.	Ins.
Buckmani-grit—		
1. Ragstone, about	2	0
2. Yellowish, sandy ragstone, about....	3	0
3. Hard, yellowish, sandy ragstone. Large double-valved *Cucullæa* showing. Bottom of the bed very uneven	0	10
4. Fine, bright-yellow sand	0	6
5. Grey, earthy marl	0	2
6. Yellowish, shelly ragstone; some *Gryphææ*. Young specimen of *Terebratula Buckmani* at the base. *Acanthothyris*, sp., at the very top. (*Hyboclypus caudatus*, Wr.: and corals, *fide* Mr. Upton.)		
Lower *Trigonia-grit.*		
7. Brown, earthy marl	0	3
8. "Lamellibranch-bed." Yellowish, ironshot ragstone, rather soft, and considerably broken up by the weather. *Pholadomya fidicula*, *Trigonia costata*, *Trigonia formosa*, *Isocardia cordata*, *Opis cordiformis*, Lyc., *Cucullæa* cf. *ornata*, *Alectryonia flabelloides*, *Cypricardia*; *Lioceras* [*Reynesella*] cf. *intermedium* 1 foot from the top..	1′ 9″ to 2′	
9. Soft, yellowish stone	0	4
10. Yellowish, ironshot stone, similar to Bed 8, with corals. Not continuous in the quarry	0	3
11. Similar stone with *Gryphæa* and *Gresslya gregaria* (?)	0	9
12. Brown, earthy marl................	0	4

On Swift's Hill there is an equally good section, the sand-bed being very conspicuous. The bed immediately overlying the sand is very uneven, as is the case in most of the sections reviewed.

THE GRYPHITE-GRIT.

The term Gryphite-grit dates back to 1834, when it was applied by Sir Roderick Murchison to those Ragstone-beds yielding specimens of *Gryphæa* abundantly in this district. A *Gryphæa* from the Ragstone-beds was first figured by Prof. James Buckman in the second edition of "The Geology of Cheltenham." under the specific name of *cymbium*.* At a later date, Lycett—taking Prof. Buckman's figure as his type—gave to the shell the name of *Gryphæa Buckmani* ;† but of late years this name has been dropped in favour of Deshayes's denomination *Gryphæa sublobata*, by which name the *Gryphæa* of the Gryphite-grit is now usually known. Mr. S. S. Buckman, however, has noticed that " the *Gryphææ* tend to alter in the later deposits of the ' intervening beds,'‡ becoming broader, more circular, and having a more pronounced expansion." The dimensions of the fossil given by Deshayes in his description are : length 80 mm., and breadth 50 mm. Mr. Buckman remarks that " these proportions do not agree with the dimensions of *Gryphæa Buckmani*, which is shown by the figure to be 70 mm. long and 65 mm. wide : it is evidently a fossil from the lower of the ' intervening beds,' because the specimens from the lower beds generally conform to such dimensions. Still less do the proportions given by Deshayes agree with those of the Gryphite-grit specimens."§ Mr. Buckman comes to the conclusion that " there may very reasonably be some doubt as to whether Lycett's *Gryphæa Buckmani* is really the same as the *Gryphæa sub-*

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* Table 7, fig. 3.

† "Proc. Cotteswold Nat. F.C.," Vol. I. (1853), p. 236.

‡ That is the beds lying between the Upper Freestone and Upper *Trigonia*-grit.

§ "Quart. Journ. Geol. Soc.," Vol. LI. (1895), p. 437.

lobata (Deshayes); but there cannot be much doubt that the Gryphite-grit fossils are distinct."

It is often difficult to indicate exactly the line of junction of this subdivision with the *Buckmani*-grit, for the Gryphite-grit need not necessarily be extremely gryphæiferous. Concerning this deposit Mr. Buckman has written: "At Kimsbury Castle . . . . . the beds are considerably bored, and . . . . polyzoa are attached to the *Gryphææ* both inside and out. Now the presence of *Gryphææ* alone points to a very slowly accumulating deposit; and these other signs bear additional testimony thereto. But that the Gryphite-grit was a slowly-formed deposit is of importance in connection with its contemporaneous equivalent in Dorset. That deposit is in many places about one-sixth the thickness. Therefore the Gryphite-grit was deposited six times as fast as the Dorset bed: and yet the Gryphite-grit was laid down very slowly."

"At Leckhampton Hill and Charlton Common the thickness of the Gryphite-grit has been stated as 5 feet. This may be regarded as a somewhat approximate measurement, which may appear too much or too little according to whether the rock be well weathered, so that the *Gryphææ* are prominently shown, or whether it be fully exposed. But between the sandy beds of the *Buckmani*-grit containing broad *Terebratula* aff. *Buckmaniana* [*Terebratula Uptoni*], and the white oolitic stone of the Notgrove Oolite are about 5 feet of very gryphæiferous ragstones. The change from the *Gryphæa*-beds to the Notgrove Oolite is well marked, but from the sandy beds of the *Buckmani*-grit to the gryphæiferous beds it is not always abrupt—indeed, it is generally somewhat gradual. The broad *Terebratula* referred to above occurs about 7 feet below the base of the Notgrove Oolite."*

Fossils, excepting the *Gryphæa* "*sublobata*," are not common; but this well-known shell may be seen in the

* "Quart. Journ. Geol. Soc.," Vol. LI. (1895), p. 438.

"toppers," or capping stones, of many dry walls. *Belemnites* (*Pachyteuthis*) *gingensis*, however, is not infrequent, and is a good fossil by which to distinguish a particular horizon. Some of the best exposures of the Gryphite-grit are to be had on Kimsbury Castle; and the rock may be again noticed in the Buckholt-Wood section; but after that it is not seen until we come to Leckhampton Hill. The floor of the quarry to the left of the tram-line on the summit of this hill is strewn with *Gryphææ*, and verily remind us that these rocks were once deposited by the sea, although now near 980 feet above its level. On Charlton Common extremely gryphæiferous beds may be seen in the line of quarries on the summit overlooking Southfield Farm, where they are about 5 feet thick. The same subdivision may be also studied in the quarry above Whittington, and again in a quarry to the east of that known as the Rolling Bank Quarry, where the Notgrove Freestone is seen above. The *Gryphææ* are very abundant in the Sudeley Hill quarry, and again in the road-section three-quarters-of-a-mile east of Withington Church. In a cutting on the Cirencester Road, at the locality marked as Lodge Farm, near Rendcombe, a considerable thickness of Upper *Trigonia*-grit is cut through, and rests upon what is, presumably, the Gryphite-grit, but more definite evidence is desirable. Indications of the same deposit—in close proximity to, if not in actual juxtaposition with the Upper *Trigonia*-grit—may be seen in the deeply-cut field-track a little under half-a-mile east of Rendcombe Church.

There are some excellent sections in the neighbourhood of Painswick Slad, such as in the quarry on the hill about a quarter-of-a-mile north of the village, and again half-a-mile west-north-west of Knap Farm. This latter quarry has been opened out in a slipped mass, and the occurrence of *Terebratula globata* indicates that the Upper *Trigonia*-grit has slipped with it. On Longridge, in the openings by the roadside, it would appear that portion of the Gryphite-grit has been excavated, and

Astarte elegans is abundant together with a smooth *Pecten*: the latter fossil of the same species as occurs so plentifully in bed 2 of the Buckholt-Wood section.

THE NOTGROVE FREESTONE.

The Notgrove Freestone or Oolite is a very distinct rock, and was so called by Mr. S. S. Buckman on account of its development in the neighbourhood of Notgrove. Lithically, it is distinct in that the oolite-granules are whitish and very prominent when the stone is at all weathered. Fossils are scarce, but specimens of *Gryphæa*, *Ostrea*, *Pecten*, and *Trigonia*, may be occasionally obtained.

In the Painswick area the Notgrove Freestone has been quarried on Kimsbury Castle; but near Cheltenham there are excellent sections on the summits of Leckhampton Hill and Charlton Common. Quarrying operations have been very extensive on the top of Leckhampton Hill.* The Upper *Trigonia*-grit, crowded with fossils, may be seen resting upon a very much bored surface of Notgrove Freestone. Large ammonites of the genus *Sonninia* from the latter deposit and also from the Gryphite-grit, are not uncommonly seen on the spoil-heaps.

At Cold Comfort the following section exposed in the quarry has been recorded by Mr. Buckman :—†

Quarry at Cold Comfort.

	Ft.	Ins.
Witchellia-grit—		
1. Grey, shelly, sandy stone, not iron-shot; *Acanthothyris* cf. *paucispina*, small forms rather common, but only single valves; larger specimens scarce. *Pseudomelania* (?) cast, *Bourguetia* (?) cast. Small elongate *Terebratula*, about	1	0

* "Quart. Journ. Geol. Soc.," Vol. XLIX. (1893), p. 512.
† *Ibid.*, Vol. LI. (1895), pp. 417-418.

	Ft.	Ins.
2. Similar stone, but no fossils were noticed	1	0
3. Greyish, rather ironshot, shelly stone. Various species of *Witchellia*, and *Terebratula Wrighti*	0	5
4. Greyish, fairly ironshot, shelly stone. The iron grains are rather angular in shape; they fall out, and leave the stone pitted. Flattish *Terebratula*. Small smooth *Pecten* rather common................	0	6
5. Somewhat cream-coloured, shelly stone, broken up, and mixed with rubbly marl. Weathered pieces show Polyzoa	1	1
Notgrove Freestone—		
6. Whitish limestone, with a more or less pinkish tinge and iron-stains, considerably bored, in places more than 1 foot vertically; [*Gervillia*, *Isocardia*, *Trigonia*] *Ostreæ* and *Gryphææ* occasionally, although the rock is generally unfossiliferous	2	3
7. Whitish limestone. "Freestone," with small whitish oolite-grains; visible	7	0

From the *Witchellia*-grit here the writer has collected *Zeilleria* spp. and *Terebratula* cf. *submaxillata*.

On the Cleeve Hill plateau the Notgrove Freestone is seen in the quarry above the village of Whittington, and in several near the Rolling Bank Quarry. At the latter place its relationship to the *Witchellia*-grit can be made out. In the southern end of the Rolling Bank Quarry the grit is seen inclined at a high angle, while the freestone is visible in a disused quarry a few yards further to the south.

One of the best sections is to be had in Farmcote Wood, near Winchcomb. Here the Notgrove Freestone

is exposed for a thickness of about 14 feet, in the lower part of which oblique lamination is very conspicuous. The Upper *Trigonia*-grit, which rests upon a bored surface of the Notgrove Freestone, is about 6 feet thick. A small excavation on the left-hand side of the road just after entering Limehill Wood from the north reveals the same subdivisions in contact. There is another equally good section by the roadside about half-a-mile due south of Farmcote* Wood Farm.

QUARRY AT THE SOUTH-WEST CORNER OF FARMCOTE WOOD.

	Ft.	Ins.
Upper *Trigonia*-grit—		
1. Grey, shelly, rubbly stone; *Terebratula globata*, *Trigonia costata*, *Pecten demissus*, *Avicula* cf. *digitata*; visible	2	3
Notgrove Freestone—		
2. Whitish oolitic limestones; top-bed much bored with a layer of *Ostreæ* sometimes adhering to the surface, but often in lenticular masses; visible	6	0

In Chedworth Woods there are numerous excavations; while on the left-hand side of the road leading to Hilcot, and close to Foxcote Hill Farm,† there is a small quarry excavated in the rock under consideration. It will be noticed that whereas at Cold Comfort the *Witchellia*-grit capped the Notgrove Freestone, here the grit is absent: the Upper *Trigonia*-grit rests directly upon the Notgrove Freestone.

QUARRY SOUTH-WEST OF FOXCOTE HILL FARM.

	Ft.	Ins.
Upper *Trigonia*-grit—		
1. Shelly stone; *Terebratula globata*, *Rhynchonella* cf. *subtetrahedra*, *Rhyn. hampenensis*, *Zeilleria Hughesi*, and *Trigonia costata*; visible....	4	0

* Often spelt Farmcott.

† Called Pegglesworth Hill on the new 1-inch Ordnance Survey Map.

Notgrove Freestone—

	Ft.	Ins.
2. Hard, in places bluish-grey, oolitic limestone, much bored; *Ostreæ* adhering to upper surface; visible	2	6

Apparently this rock has been reached in a quarry at Hillcot, a mile west-south-west of Withington Church, since the walls near have built into them pieces of much-bored freestone. In the quarry on Swift's Hill are two beds (the upper much bored vertically), which have a joint thickness of 1 foot 4 inches. These Mr. Buckman would regard as Notgrove Freestone.

THE *WITCHELLIA*-GRIT.

Of the several subdivisions of the Inferior Oolite in this district, not one is really so important to the geologist as that now under consideration. This is because it yields ammonites somewhat abundantly, and their occurrence enables us to correlate the deposit with the beds of the same date in the Dorset-Somerset area. Part of the *Witchellia*-grit was called by Dr. Wright the *Perna*-bed; but that portion of the deposit which yielded the lamellibranch so abundantly in the past appears to be quite worked out now. The occurrence of ammonites at Cold Comfort (*vide* page 118) has been known for a long time. Prof. James Buckman, in the "Geology of Cheltenham," mentions "*Ammonites læviusculus.*" A quarry above and to the south of Lineover Wood, on the left-hand side of the main-road from Gloucester to Oxford, near the eleventh milestone from the former place, affords another section in the *Witchellia*-grit, which has been recorded by Mr. Buckman. The reading given below differs from his in that bed 2 is assigned to the Upper-*Trigonia*-grit.

Quarry near Lineover Wood.

Upper *Trigonia*-grit—

	Ft.	Ins.
1. Hard, grey, shelly ragstone, with numerous *Trigoniæ* (impressions) and the usual brachiopods	2	0

	Ft.	Ins.
2. Yellowish, slightly ironstained rag-stone; gasteropods in sections, *Serpula*, *Avicula* spp.	0	11
Witchellia-grit—		
3. Grey, shelly, oolitic stone, somewhat ironstained, small *Acanthothyris* spp. Top-layer much bored	0	10
4. Greyish-brown, very shelly stone, somewhat flaggy	0	4
5. Yellow earthy layer................	0	1
6. Greyish-brown, shelly stone; *Astarte elegans*, *Modiola*, *Ostrea*, dwarf *Gryphæa*	1	8
Notgrove Freestone—		
7. White, very oolitic stone, very much resembling freestone		

The geographical distribution of the *Witchellia*-grit in the Cotteswold country is very limited. It is best studied in the quarry at Cold Comfort, where *Terebratula Wrighti* is a somewhat abundant fossil, occurring chiefly in the earthy marl which separates the rubbly rock. On the Cleeve Hill plateau it is exposed at the southern end of the Rolling Bank Quarry, where it has yielded several ammonites, together with *Terebratula Wrighti*, *Terebratula* cf. *submaxillata*, and *Trigonia* sp.

THE *BOURGUETIA*- AND *PHILLIPSIANA*-BEDS.

These strata occupy an area even more restricted than the *Witchellia*-grit. They are found only on the Cleeve Hill plateau, and are best studied in the Rolling Bank Quarry, distant about 650 yards from the Rising Sun Hotel. The *Bourguetia*-beds are about 14 feet thick, and were thus called on account of their containing the large gasteropod *Bourguetia*. These beds are also interesting on account of the presence of lamellibranchs of exceptionally large dimensions, such as *Myoconcha* and *Alectryonia*; and, occasionally, large nautiloids may

be found. The *Phillipsiana*-beds yield mainly brachiopods, such as *Terebratula Phillipsiana*, called by the quarrymen, "lion's claws," *Terebratula Buckmaniana*, *Zeilleria anisoclines*, and *Rhynchonella* cf. *quadriplicata*. There is also a species of *Acanthothyris*. The top-bed of the *Phillipsiana*-beds is a hard bluish-grey stone, much bored by annelids and *Lithodomi*. It will be noticed that the fauna contained in these beds is somewhat special, and since, throughout the Cotteswold country, it is only on the Cleeve Hill plateau that we have beds which are of *Sauzei* date, it will be understood that the fossils obtained are of particular interest. The following record of the beds exposed in the Rolling Bank Quarry is mainly by Mr. Buckman :—*

THE ROLLING BANK QUARRY, CLEEVE HILL.

	Ft.	Ins.
Clypeus- and Upper *Trigonia*-grits—		
1. Yellow ragstones, with *Terebratula globata*. In the lower part are numerous specimens of *Trigoniæ* and *Rhynchonella angulina*......	15	0
Phillipsiana-beds—		
2. Bluish-grey stone, sharp fracture. Bored by annelids and *Lithodomi*	0	4
3. Similar stone, not bored, but somewhat rounded in places, with sand pockets	0	6
4. Similar deposit; three beds with sandy partings. *Terebratula Phillipsiana*, var., sparingly	5	0
5. Similar splintery grey limestone, with *Terebratula Phillipsiana* and *Ter. Buckmaniana* abundant. "*Rhynchonella quadriplicata*," *Acanthothyris*, *Zeilleria anisoclines*. Two beds with sandy partings, and a sandy base with oysters........	2	3

* "Quart. Journ. Geol. Soc.," Vol. LIII. (1897), p. 609.

	Ft.	Ins.
6. Similar massive stone; *Terebratula Phillipsiana*, "*Rhynchonella quadriplicata*." Large *Bourguetia striata*	2	0
Bourguetia-beds.		
7. Greyish, shelly stone, with brownish patches and infillings; *Ctenostreon pectiniforme* or *proboscideum*, and *Bourguetia striata*	2	3
8. Grey stone in several beds. Lamellibranchiata are numerous, and are particularly noticeable for their unusually large size. Large, much plicate *Ostrea*, *Myoconcha*, etc. Large *Nautilus*	7	0
9. Grey, shelly limestone, somewhat bored	1	6
10. Limestone	0	9
11. Limestone	3	4

If the quarry were excavated deeper, the *Witchellia*-grit should be seen below the *Bourguetia*-beds.

In a quarry a little to the east of the Rolling Bank the *Phillipsiana*-beds may be again studied. The "bored-bed" is visible, and *Terebratula Buckmaniana* may be collected. Just over half-a-mile north-west by west of Cotehay Farm, near Brockhampton, a small quarry reveals the top-bed of the *Phillipsiana*-beds much bored, and containing a few examples of *Terebratula Buckmaniana*. These beds of the hemera *Sauzei* do not extend across the Charlton Abbots Valley, for—as has been already pointed out—in Farmcote Wood the Upper *Trigonia*-grit rests directly upon the Notgrove Freestone.

Although the deposits laid down during ten hemeræ, and belonging to the Inferior Oolite, have now been described—and there yet remain those beds accumulated during the hemeræ *Garantianæ* to *fuscæ* inclusive—still the sequence is not complete in the Cotteswold Hills, for in Dorset, between the deposit which was laid down during the hemera *Sauzei* and that in the *Garantianæ*

hemera are beds which were deposited during the hemeræ *Humphriesiani* and *niortensis*. No deposits of these dates have yet been detected in the Cotteswold Hills, and consequently there is a break in the sequence of the strata. Even where the Upper *Trigonia*-grit rests upon the *Phillipsiana*-beds there is a considerable gap. It has often been stated that the *Humphriesianum*-zone occurs in the Cotteswolds, but this is through giving the zone too great a range on account of incorrect palæontology.

THE UPPER *TRIGONIA*-GRIT.

The greater mass of the Upper *Trigonia*-grit was laid down during the hemera *Garantianæ*. It was included by Dr. John Lycett in his "Spinosa Stage" on account of the occurrence of the fossil now known as *Acanthothyris spinosa*, but then as *Rhynchonella spinosa*.*

Of all the subdivisions of the Inferior Oolite, the Upper *Trigonia*-grit is the most frequently exposed. The rock is a hard, greyish, rough limestone, somewhat flaggy, and full of fossils. These are usually very difficult to extract from the limestone, but sometimes they may be obtained from the less compact portion, or, better still, from the fossil-collector's standpoint, off the spoil-heaps. As the stratigraphical term given to the deposit of the hemera *Garantianæ* implies, *Trigoniæ* are of frequent occurrence, and of shells belonging to the same class we may notice specimens of *Avicula*, *Limea*, *Myacites*, *Gresslya*, *Pholadomya*, *Pecten*, etc. The brachiopods include *Terebratula globata* and varieties, *Zeilleria Hughesi* (characteristic of this deposit), *Aulacothyris carinata* (rare in this district), *Rhynchonella* cf. *subtetrahedra*, *Rhyn. angulina*, *Rhyn. hampenensis*, and *Acanthothyris spinosa*. A few gasteropods and echinoids may also be obtained.

The top-bed of the Upper *Trigonia*-grit is often seen to have numerous oysters attached to its upper surface,

* "The Cotswold Hills" (1857), pp. 60, 66, 67.

and—as may have been noticed—the deposit usually rests upon a bored surface of the underlying rock-subdivision. And further, it will doubtless have been remarked that the Upper *Trigonia*-grit is not always found resting upon the same subdivision, for in the preceding pages sections have been recorded in which it has been observed to rest non-sequentially upon the Upper Freestone, Lower *Trigonia*-grit, *Buckmani*-grit, Gryphite-grit, Notgrove Freestone, *Witchellia*-grit, and *Phillipsiana*-beds.

I have already indicated numerous sections where the Upper *Trigonia*-grit may be studied (see pp. 89-90, etc.) It is not preserved on any of the outliers, and has been removed by denudation from off the ridge between Scotesquar and Cud (Spoonbed) Hills. At Kimsbury Castle it is exposed; and again in the Buckholt-Wood Quarry, where it may be best seen in an opening on the other side of the wall which runs along the top of the quarry. Numerous sections in Cranham Wood show the Upper *Trigonia*-grit resting upon the Upper Freestone. At Birdlip similar phenomena obtain, but the passage into the *Clypeus*-grit, with the almost unfossiliferous limestones separating the grits, may also be studied.

The Upper *Trigonia*-grit is worked on the summit of Leckhampton Hill, where it rests upon a very much bored surface of Notgrove Freestone. In the Rolling Bank Quarry this deposit yields some remarkable forms of *Terebratula globata;* and *Rhynchonella angulina* is abundant. The sections in Farmcote Wood have already (pp. 119, 120) been noticed. Other localities where it may be studied are: where the Banbury line crosses the Stow road at the foot of Hampen Hill, formerly a well-known section yielding several species of echinoids; in the railway-cutting at Ossington Hill, to the east of Andoversford; at Compton Abdale; on the left-hand side of the road to Colesbourne, about a third-of-a-mile north-north-west of North Cerney Church; in the cutting on the same road near Lodge Farm; in a quarry three-quarters-of-a-

mile south-by-west of Colesbourne; on the hill-side south of Hill Barn, near Upper Coberley; at Hill Cot; and at the Cowley-Wood Quarry. At all these sections the faunal and lithic characters of the rock are the same.

At the bottom of the valley about a third-of-a-mile east-south-east of Brimpsfield Church we see the *Clypeus*- and Upper *Trigonia*-grits resting upon a slightly-bored surface of Upper Freestone. Several faults cross the valley near this spot. Here, indeed, the upper portion of the Upper Freestone is seen almost on a level with Upper Lias clay; while a mile to the north Fullers' Earth is brought almost on a level with the Upper Freestone of this section. On the left-hand side of the road descending to the brook from Caudle Green are exposed the *Clypeus*- and Upper *Trigonia*-grits, and Upper Freestone. Separating the grits are almost unfossiliferous whitish limestones, and similar transition-beds may be observed on the south side of the road three-quarters-of-a-mile west-north-west of Miserden Church. Quarries in the Upper *Trigonia*-grit are to be seen a quarter-of-a-mile north-east by north of Blacklanes Farm, near Brimpsfield, and again a little over a quarter-of-a-mile to the south-east of that farm.

About three-quarters-of-a-mile south-west by west of the Church in Brimpsfield are two very interesting sections. The first is situated to the south of the road from Brimpsfield to Climperwell, on the north side of a small but conspicuous valley.

SECTION IN QUARRY NEAR BRIMPSFIELD.

(Seven-tenths-of-a-mile south-west by west of the Church.)

	Ft.	Ins
Upper *Trigonia*-grit—		
1. Greyish, shelly limestone; *Terebratula globata*, *Zeilleria Hughesi*, *Rhynchonella* cf. *subtetrahedra*, *Rhyn.*		

	Ft.	Ins.
hampenensis, Rhyn. angulina, Acanthothyris spinosa, Trigonia, Avicula, Ctenostreon ; Oppellia subcostata 19 inches above the Upper Freestone	8	0
2. Brownish earthy layer, with pebbles of Upper Freestone	0	4
Upper Freestone—		
3. Hard, whitish, oolitic limestone, top-bed bored. *Terebratula fimbria* noticed 2 feet 8 inches down ; visible about	3	0

At this quarry and the next to be noticed *Zeilleria Hughesi* is abundant. The record of the ammonite is important.

Quarry near Brimpsfield.

(Nine-tenths-of-a-mile south-west by west of the Church.)

	Ft.	Ins.
Clypeus-grit—		
1. Whitish, oolitic limestone, passing down into a brownish rock in which *Terebratula globata* is abundant ; about..................	6	0
Upper *Trigonia*-grit—		
2. Grey, shelly limestone, surface of top stratum covered with *Ostreæ ; Terebratula globata* and varieties, *Rhynchonella* cf. *subtetrahedra, Rhyn. angulina, Rhyn. hampenensis, Rhynchonella* sp., *Acanthothyris spinosa, Avicula, Lima, Trigonia, Ostrea*, etc.	6	6
3. Brownish earthy deposit, with pebbles occasionally	0	2
Upper Freestone—		
4. Whitish, oolitic freestone, top-bed bored ; *Terebratula fimbria* in stratum 2 feet 6 inches down ; visible	4	0

This section is certainly one of the best in the Cotteswolds of the Upper *Trigonia*-grit. It is especially noticeable on account of the occurrence, somewhat abundantly, of good specimens of *Acanthothyris spinosa* and *Zeilleria Hughesi*. The exact horizons at which *Terebratula fimbria* was noticed were at 30, 35, and 39 inches down. Oysters may be again noticed adhering to the surface of the Upper *Trigonia*-grit. Above are exposed in the quarry about 4 feet of deposit which I have classed as *Clypeus*-grit. The lower 2 feet of rock contain numerous examples of *Terebratula globata*, but no specimens of *Rhynchonella* were observed. Above, the rock is whitish, and contains very few fossils; and a similar deposit is seen in the north side of the road along the top of the quarry, in which a specimen of a *Terebratula*, near to *birdlipensis*, was found. In the road-side rock to a thickness of a foot was measured, and allowing a similar thickness for difference in level between that seen in the quarry and that in the road, we have the measurement recorded above. The section at Dunley has already been noticed (page 109): another exposure may be examined just over a mile to the west-south-west.

On the ridge separating the Painswick and Slad Valleys are several quarries. One, on the outskirts of the wood about a quarter-of-a-mile to the north-west of the Slad village, shows this deposit resting upon what appears to be Gryphite-grit. The top-bed of the latter is bored, and in places stained a reddish colour. Similar phenomena may be observed in the road-cutting some two or three hundred yards to the south-west of Cats Wood, on the east side of the valley. Just under half-a-mile south-west of the Slad village is the quarry known as Worden's Quarry. The section presented is very interesting: it shows what is known as the "Upper Coral-bed." To quote Edwin Witchell, "This bed, so far as is at present known, is confined to the neighbourhood of Stroud; it lies upon the Upper *Trigonia*-grit. It is seen along the ridge separating the Painswick and Slad valleys, also at Stroudhill and Rodborough hill. In a

quarry on the hill overlooking the Slad village, known as Worden's Quarry, the bed consists of two or three thin layers of coral, separated by rubbly Oolite, in the whole about three feet thick. In the quarry on the top of Stroudhill it is about three feet thick, but it does not appear in the ragstone quarry in the Bisley road, about one hundred and fifty yards distant. In a quarry on Rodborough hill, below the Minchinhampton road and between it and the road leading to Mount Vernon, it appears in a broken-up condition; but in the adjacent quarries it is regularly bedded. The rock appears in patches of brown coarse grit, layers of coral, and a whitish-brown mud cement. It is rather flaggy, and when weathered its fossils are seen in a high state of preservation. *Pecten articulatus* is abundant; *Terebratula globata*, *T. submaxillata* [*? lentiformis*], *Waldheimia* [*Zeilleria*] *Waltoni*, and *Lima bellula*, are the characteristic fossils, and are moderately abundant. In the bed at Stroudhill some beautiful examples of *Stomechinus intermedius*, Agass., *Pedina rotata*, Wr., *Cidaris Bouchardi*, and *Hemicidaris* (sp.) have been found."* Mr. R. F. Tomes wrote of its stratigraphical position that it "occurs in the upper part of the Upper Trigonia Grit." It only yielded that geologist *Isastræa tenuistriata*, *Isastræa* sp., and *Thamnastræa* sp. From this deposit at Worden's Quarry the writer has collected *Zeilleria Waltoni* and *Terebratula lentiformis*. From the same rock here Mr. Charles Upton has obtained *Magnotia Forbesi* and *Polycyphus normannus*: both exceedingly rare sea-urchins in this district. The record of the former is possibly new for the Cotteswolds. It should be mentioned that the *Rhynchonellæ* from this quarry frequently have adhering to them beautiful specimens of *Thecidella*—a minute brachiopod.

* "The Geology of Stroud" (1882), p. 60; *vide* also "Proc. Cotteswold Nat. F.C.," Vol. IX. (1890), p. 300.

THE *CLYPEUS*-GRIT.

The *Clypeus*-grit has been thus called on account of the occurrence—but only abundantly near the top—of the cake-like sea-urchin, *Clypeus Ploti* (or *sinuatus*). The *Clypeus*-grit, which was called the "Pholadomya Grit" by Dr. Lycett, comprises pale coarse-grained oolite with beds of finer texture. In certain beds *Terebratula globata* is exceedingly abundant, to the exclusion of almost any other shell.

On the escarpment this rock is not so frequently seen, having been removed by denudation. It is, however, exposed in the face of the hill in the grounds belonging to the George Hotel at Birdlip, and of this neighbourhood Prof. James Buckman wrote, "The platform upon which the houses at Birdlip stand rests on this bed, which is well exposed by the denudation of the Fuller's earth. Here the plough on the Stone-brash turns up this urchin [*Clypeus Ptoti*] in large quantities; the same is the case in the Stow district, where we have frequently seen it gathered up in heaps for removal from the barley-field, and have not always succeeded in convincing our bucolic friends that it was not an annual production."

A quarry half-a-mile south-east by east of the Seven Springs affords the following section :—

QUARRY NEAR THE SEVEN SPRINGS.

	Ft.	Ins.
Clypeus-grit—		
1. Rubbly stone, pisolite-spherules; *Clypeus Ploti*, *Anabacia complanata*, *Myacites*, *Pholadomya* spp., *Lima gibbosa*, numerous examples of *Terebratula globata*: visible ..	2	0
2. Grey, fine-grained rock; few fossils ..	2	2
Upper *Trigonia*-grit—		
3. Grey, compact rock, very shelly; a layer of *Ostreæ* on upper surface; *Gryphææ*, *Pecten* spp., *Avicula*, *Terebratula globata*, *Rhynchonella hampenensis*, etc.	5	4

Clype.

On Cleeve Hill the Upper *Trigonia*-grit is exposed in the Rolling Bank Quarry, and yields numerous examples of *Terebratula globata;* and *Clypeus Ploti* is not uncommon. Around Hampen, to the east of Andoversford, are several exposures, and it may be again studied in the south bank of the stream at Compton Abdale. At the north-eastern corner of Yanworth Common there are old workings in the *Clypeus*-grit—easily recognised by its large oolite-granules, which much resemble pisolite-spherules. In a lane-cutting about two-fifths of a mile east of Rendcombe the Upper *Trigonia*- and *Clypeus*-grits may be studied, while near the gate some small ponds indicate the presence of the Fullers' Earth.

Just over a mile-and-a-half east of Elkstone* Church is an old quarry, in which there is an excellent section of the *Clypeus*-grit. *Terebratula globata* is again most abundant, but it will be noticed that this specific name covers a number of varieties. Specimens of *Clypeus Ploti*, *Myacites*, *Lima*, *Pholadomya*, and *Gresslya*, may be collected. The same deposit is to be observed about half-a-mile to the north-west again, at the junction of the Combend and Elkstone roads.

In the neighbourhood of Brimpsfield sections are numerous. The quarry a little over a quarter-of-a-mile to the south-east of Blacklanes Farm exhibits the basement portion of the *Clypeus*-grit, which is best seen at the southern end of the opening.

QUARRY NEAR BLACKLANES FARM, BRIMPSFIELD.

	Ft.	Ins.
Clypeus-grit—		
1. Rubbly, somewhat flaggy stone, large oolite-granules; *Pecten*, and shell débris; visible	2	6
Upper *Trigonia*-grit—		
2. Somewhat massive-bedded, greyish, shelly stone; *Ostrea*, *Pecten* spp.,		

* Often spelt Elkston.

	Ft.	Ins.
Serpula, Lima gibbosa, Rhynchonella hampenensis, Rhyn. aff. *subtetrahedra, Rhyn. angulina, Acanthothyris spinosa, Zeilleria Hughesi*; visible	7	0

About three-quarters-of-a-mile west-north-west of Miserden Church some unfossiliferous limestone beds separate the Upper *Trigonia*- and *Clypeus*-grits: and, finally, we see the last-mentioned deposit in the lane-sides a little to the south-west of Cats Wood. A small excavation, however, should be mentioned near Stoney Hill Farm, Caudle Green, as yielding a number of specimens of the variety of *Terebratula globata* known as *birdlipensis*.

THE WHITE LIMESTONE.

In the neighbourhood of Stroud, immediately underlying the Fullers' Earth and above the "globata-bed, is . . . a whitish-brown limestone, containing locally *Terebratula globata*, which in its upper portion on Rodborough Hill becomes a fine-grained white limestone. This limestone is remarkably persistent; it everywhere underlies the Fuller's Earth, and in the lower Cotteswolds it passes into freestone."* Elsewhere† Witchell has written, "In his Memoir, Prof. Hull mentions a rubbly-white oolite as occurring at the top of the formation immediately below the Fuller's Earth, which he has named the 'Clypeus Grit.' This rubbly-white oolite occupies the same position in the Stroud district, but the 'Grit' is, I think, the next bed below, and is described by Prof. Hull as occurring throughout the north-eastern Cotteswolds—at Colesbourne, around Brimpsfield, at Stow, Rissington, the high land from Icomb Camp to Burford, Swinbrook, and the north and south sides of the Evenlode."

* "Geol. of Stroud" (1882), p. 62.
† "Proc. Cotteswold Nat. F.C.," Vol. VII. (1880), pp. 117-135.

This "White Oolite," Mr. Buckman considers, may be of the hemeræ *zigzag* (*pars*) and *fuscæ*. Where seen, it contains few fossils, but *Terebratula globata*, *Trigonia* sp., and *Pecten* spp. have been recorded. This rock is presumably represented by the white oolitic limestone of the section nine-tenths of a mile south-west by west of Brimpsfield Church, in which section it was classed with the *Clypeus*-grit.

The actual junction of the Inferior Oolite with the Fullers' Earth has been observed by Mr. Buckman in the eighth railway-cutting from Andoversford on the line to Cirencester, where the beds are affected by a fault.

SECTION IN THE EIGHTH RAILWAY-CUTTING FROM ANDOVERSFORD.

	Ft.	Ins.
Fullers' Earth—		
1. Blue Clay		
White Limestone, or "Transition Strata."		
2. Hard, reddish limestone, with darker grains	0	7
3. Clayey marl	0	4
4. Rubbly brown limestone, with coarse dark grains	3	0
5. Brown decomposed paste	0	3
Clypeus-grit—		
6. Rock with *Terebratula globata* and *Clypeus Ploti*..................		

In his description of this section, Mr. Buckman observes that "It may be convenient to speak of the beds 2–5, connecting the *Clypeus*-grit proper with the Fuller's Earth clay, as 'transition strata'; and they should be compared with a similar series shown in the fifth cutting west of Bourton-on-the-Water Station.* It will be noticed that there is a very considerable difference between them, both in thickness and in general lithological details."† The rocks exposed in the cutting

* "Proc. Cotteswold Nat. F.C.", Vol. IX. (1890), p. 123; *vide* also "Quart. Journ. Geol. Soc.," Vol. XXXIX. (1883), pp. 225, 237.

† "Proc. Cotteswold Nat. F.C.", Vol. X. (1892), pp. 99, 100.

near Bourton-on-the-Water referred to in the above quotation have been compared by Mr. E. A. Walford to the Chipping Norton Limestone: a deposit which forms the highest part of the Inferior Oolite Series in that area. The logical conclusion derived from the above statements is, of course, that the White Limestone of the Stroud area is most probably the equivalent of the Chipping Norton Limestone, but—although this may be the case—before accepting it more detailed information is desirable. I am inclined to think that the two deposits are distinct, and that the Chipping Norton Limestone comes above the White Limestone.

THE HISTORICAL GEOLOGY OF THE INFERIOR OOLITE SERIES.

Attention may now be directed to the historical geology of the Inferior Oolite Series. The exact restoration of the western coast-line of the sea in which the Inferior Oolite was deposited is somewhat uncertain, but it is improbable that, even in its greatest extent, it stretched far beyond the present high ground, composed of Primary and Archæan rocks, on the line of the Malvern fault. After a microscopic examination of many pieces of rock collected from different horizons in the Inferior Oolite, Mr. E. B. Wethered regarded "the detrital residue, as a whole, as having been derived from crystalline felspathic rocks, and not from the denudation of stratified ones."* The occurrence of minerals such as would be derived from the Malvernian rocks cannot, of course, be advanced as positive evidence that the Malverns were above sea-level during the time when the Inferior Oolite Series was deposited, but their occurrence is suggestive.

The lithic structure of the upper portion of the Upper Lias is variable, for, as already stated, sand was being deposited at one locality contemporaneously with clay at another. Thus at Bredon Hill the line of demar-

* "Quart. Journ. Geol. Soc.," Vol. XLVII. (1891), pp. 565, 566.

cation between the Lias and Inferior Oolite happens to be very distinct as regards lithic structure: the sandy beds of the hemera *scissi* resting directly upon a clay deposit. At Haresfield Beacon, however, there is no such distinct division as regards lithic structure. Here, the Cotteswold Sands and Cephalopoda-bed are correctly "transition beds," as will be seen from a study of the deposits. First and lowest is a deposit of yellow sand; above that is the Cephalopoda-bed, marly strata with some lime; then succeed the sandy ferruginous beds, and, as Witchell has written, "each succeeding bed appears to be less sandy and more calcareous until the formation becomes an Oolitic Limestone. In the lowest bed the oolitic structure can scarcely be observed, but as the rocks become more calcareous, the oolitic granules appear; they are, however, small and sparsely distributed."

The study of the organic remains embedded in the rocks affords the greater number of the facts by which it is possible to unravel the history of any deposit. By a study of the Ammonoidea and Brachiopoda of the Dorset-Somerset area and the Cotteswold Hills, Mr. Buckman is enabled to state, "that from the time of the Upper Lias until the *Parkinsoni*-zone [Upper *Trigonia*- and *Clypeus*-grits], this sea [the Dorset-Somerset or Anglo-Norman] was cut off from the Cotteswold area by some extensive upheavals, thus accounting for the difference in fauna."*

In places, as already stated, there is evidence of an erosion having taken place in the Harpoceratan Age, and this was caused by certain movements along lines of weakness.† The exact date of this upheaval and erosion is at present uncertain: it was certainly post-*variabilis* and pre-*scissi*. The top portion of the *scissum*-beds is also often bored: such is the case at Cooper's Hill, and it is again noticeable at

* "Proc. Cotteswold Nat. F.C.," Vol. IX. (1890), p. 387.
† *Vide* "Quart. Journn. Geol. Soc., Vol. LIX. (1903), p. 451.

Puckham. This would point to a slight pause in the deposition of sediment. Above the *scissum*-beds comes the Lower Limestone. The top-bed, or the "Dapple-bed," at Huddingknoll Hill, contains many small quartz pebbles, and also pebbles of oolitic rock. The quartz pebbles have most probably come from the Forest of Dean or May Hill: for in some of the soft, greenish, shaly bands in the May Hill Sandstone at this hill are many such pebbles, and they are very easily separated from the matrix. The shaly matter may be dissolved from around the quartz pebbles by merely immersing the rock in water. It is, then, very probable that May Hill is the locality whence these little pebbles have come, and the conclusion is that currents flowed from May Hill towards the Horsepools. Such currents might cause pene-contemporaneous erosion, and the presence of pebbles of oolite in the same bed would seem to substantiate this view.

While the *scissum*-beds and Lower Limestone were being deposited, life appears to have been somewhat scarce. True, certain brachiopods and a few fossils belonging to other classes are found in the *scissum*-beds, but otherwise organic remains are rare. Then—excepting, perhaps, crinoids—life does not appear to have been prolific in those areas where the Lower Limestone was accumulating. In marked contrast thereto is the fauna of which we have evidence in the fossils of the Pea-grit. Nearly all classes of animal life flourished in that portion of the sea where the pisolite-spherules were in the course of formation.

The geographical distribution of the typical Pea-grit, however, is very limited: to the south it gradually disappears, but it is probable that the upper portion of the Lower Limestone of the Stroud area is the equivalent in time of the lower portion of the Pea-grit at Leckhampton. The area over which typical Pea-grit was formed certainly extended as far west as Robins' Wood Hill, and as far north as Oxenton. With one exception, to my

knowledge, true Pea-grit is not found to the east of the Charlton Abbots Valley. This exception is the bed of pisolitic limestone in the small disused quarry in the valley east of Sudeley Lodge, or about a quarter-of-a-mile north of Sudeley Park Farm. Eastwards I have not observed it farther than Cassey Compton, where it is seen in the east bank of the road about 350 yards to the north-east of the hamlet. In Monkscombe, about three-quarters-of-a-mile east-south-east of Colesbourne, it is well exposed, the pisolite-spherules lying about in a loose state on the ground. In an easterly direction a brownish-yellow arenaceous deposit constitutes the Pea-grit equivalent ; while at Bredon Hill, hard, massive, shelly limestones replace it. A thin stratum of somewhat pisolitic rock, however, *does* occur on Bredon Hill, for I have found indications of such on the north face, but its lithic structure can hardly be described as typical. The organic remains in the Pea-grit-equivalent at Bredon Hill are very fragmentary, and probably there was a shore-line not far distant to the west. That the time occupied in the deposition of the Pea-grit was of considerable duration is shown by the pisolite-spherules being frequently encrusted with Polyzoa and small oysters. The coral-bed which occurs on the top of the Pea-grit can be traced from Haresfield Beacon in a north-easterly direction to Crickley Hill, and eastwards to Coberley, but it has not been noticed on the Stroud side of the Slad Valley or on Rodborough Hill.*

During the formation of the Lower Freestone one pene-contemporaneous erosion at least took place, as is evidenced by the bed of conglomerate forming the roof of the Whittington mine. That the Oolite Marl was laid down in a sea quite cut off from the Anglo-Norman area of deposition is clearly indicated by the fact that *Terebratula fimbria* and several other brachiopods are only found in the Cotteswold Hills ; while the species common to Somerset, Dorset, and Normandy, are *not* found in

* "The Geology of Stroud" (1882), p. 45.

the Cotteswolds. Conditions very similar to those under which the Lower Freestone was deposited prevailed during the formation of the Upper Freestone. The evidences of life, however, are more abundant in the latter deposit, and in places many forms flourished.

At the close of the hemera *bradfordensis*—in other words, after the Upper Freestone had been deposited—earth-pressures affected the sea-floor of this district. It would appear that this denudation was brought about by a force acting north-westward (fig. 7, A) and another acting south-eastward (B), which produced a main axis (C). Forces then acting south-westward (fig, 8, D) and north-eastward (F) produced lateral axes as F and G, and even compressed the main one. The flexures having been

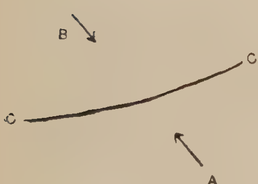

FIG. 7.

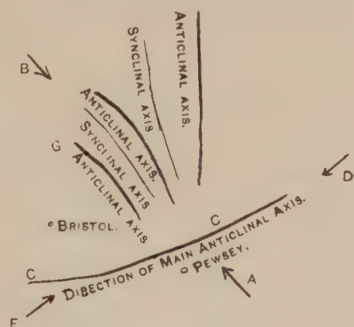

FIG. 8.

produced, the anticlines suffered erosion, so that at Birdlip a considerable thickness of rock was removed, and, probably, a still greater mass along the lines of the vales of Moreton and Bourton. In the synclinal areas deposition continued, and it is, consequently, in the area of maximum depression that the sequence from the Upper Freestone to the Ragstones should be investigated. In order to do this, attention must be given to that large tract of country known as the North Cotteswolds. Here, around the little village of Condicote and the country-town of Blockley, may be observed, between the Upper

Freestone and Lower *Trigonia*-grit, in ascending order, the Blockley Clay, Harford Sands, Lower Snowshill Clay, Tilestone, and Upper Snowshill Clay—deposits not often heard of. When one considers that the thickness of these deposits is probably close upon 90 feet, it will be understood for what a long time denudation must have proceeded in the Birdlip area, where not one of these deposits of the hemera *concavi* was laid down. The time during which the Birdlip anticline suffered erosion is equal then to at least the time it took to deposit 90 feet of rock—mostly composed of fine sediment.

This elevation of the sea-floor along certain lines, and corresponding depression along others, caused the Blockley Clay to be laid down over a very small area; but the Harford Sands extended much farther—to the Cleeve Hill plateau, and possibly beyond. But then there were renewed earth-movements, and the result was, that the area of deposition was again contracted, so that the Lower Snowshill Clay has a very restricted geographical extent. The Tilestone, however, has a greater geographical distribution, and in places should be found to overlap and rest non-sequentially upon the Harford Sands. This it appears to do, for "about four-and-a-half miles south-south-east [of Guiting Hill, near Temple Guiting], the Harford cuttings show some 5 feet of a freestone characterized by small *Ostreæ*, overlying the Harford Sands. I presume this is the same bed [as at Guiting Hill] in an attenuated condition, and without any distinct deposits of Snowshill Clay."*

And the Upper Snowshill Clay overlapped the Tilestone, for in an opening by the "Roadstone Hole," on Cleeve Hill, it is seen resting upon the Harford Sands. It even overlapped this deposit, for at Charlton Common it is found resting upon the Upper Freestone.

The depression of the Birdlip anticline, however, was not yet sufficient for the Upper Snowshill Clay to extend farther in this direction, so that Leckhampton

* S. S. Buckman, "Quart. Journ. Geol. Soc.," Vol. LVII. (1901), p. 137.

Hill is its limit. Erosion of the Birdlip anticline continued even after the hemera *concavi* had passed, and it was probably not until near the close of the hemera *discitæ* that this erosion was stopped by the anticline becoming completely submerged.

At the south-western corner of Leckhampton Hill the Lower *Trigonia*-grit is seen resting directly upon the Upper Freestone, and the former deposit has a very marked conglomerate at its base, a foot or more in thickness.

Subsidence then continued, and the upper portion of the Lower *Trigonia*-grit was probably deposited over the well-planed surface of the Birdlip anticline. The rate of the movement of subsidence does not appear to have allowed of the derivation and rounding of so many pebbles, for in the sections near the "Air Balloon" and at Cuckoo Pen, a thin earthy deposit—with but few pebbles—marks the line of division between the Ragstones and the Freestone-beds. As already remarked, it is probable that the upper portion of the Lower *Trigonia*-grit extended over the Birdlip anticline; but as a subsequent erosion—the Bajocian Denudation—removed all the rock down to and below the plane of the former erosion, the question as to whether that anticline was actually covered by the upper portion of the Lower *Trigonia*-grit, or was not submerged until the commencement of the time when the *Buckmani*-grit was laid down, must, to a certain extent, remain open. The results of the denudation which commenced at the close of the hemera *bradfordensis* may be thus diagramatically represented, from Cleeve Hill to Birdlip (fig. 9).

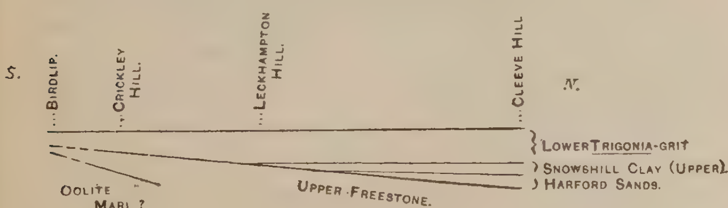

Fig. 9.

Subsidence continued, and the superincumbent beds were successively formed during a period of long quiescence, during which marine life flourished. The area over which the deposits of the hemera *Sauzei* (*Bourguetia*- and *Phillipsiana*-beds) were laid down cannot be definitely stated: it is probable that had Bredon Hill suffered less from Quarternary denudation these deposits would have been seen, with possibly beds of later date (hemera *Humphriesiani**) above. As it is, the deposits of the hemera *Sauzei* occur only on the Cleeve Hill plateau, and another denudation is responsible for this phenomenon. Since it occurred at the close of what Renevier called the Bajocian Age, it is known as the Bajocian Denudation.† The causes effecting it seem to have been very similar to those which produced the Aalenian Denudation at the close of the hemera *bradfordensis*; but this time the flexures were much more marked. The anticlinal and synclinal axes were very nearly repetitions of the former lines of weakness, and this fact illustrates the geological axiom, that a movement along a line of weakness may be frequently repeated.

The details of the phenomenon known as the Bajocian Denudation were based upon the careful work recorded in Mr. S. S. Buckman's paper on "The Bajocian of the Mid-Cotteswolds." The appearance and disappearance, if we may so term it, of certain beds between the Upper Freestone and Upper *Trigonia*-grit had always been a difficulty to Cotteswold Geologists, but the theory of the removal by denudation soon elucidates matters. Mr. Buckman did not at first connect the phenomenon with upheaval, but when this suggestion had been made by Prof. T. Groom, and he had obtained more evidence on the subject, he expressed his concurrence with that suggestion—that it was a case of the denudation of very slight anticlines.

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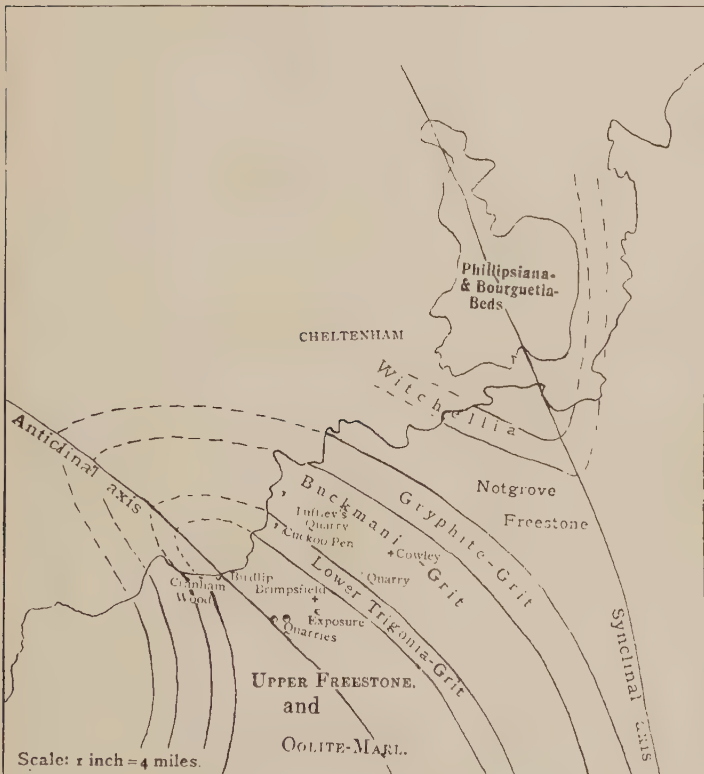
* Or *Blagdeni*.

† "Quart. Journ. Geol. Soc.," Vol. LVII. (1901), p. 129.



Sketch-map showing the area of the different beds upon which the Upper *Trigonia*-grit was deposited after the Bajocian Denudation.

For the present purpose the exact limits of the area of deposition of the beds of *Sauzei* date matter little; suffice it to say that the anticlines and synclines of the previous denudation were buried beneath the Ragstones, from the Lower *Trigonia*-grit to *Phillipsiana*-beds inclusive—the latter, perhaps, with newer strata above again. Thus all traces of the previous denudation were hidden, but in the Birdlip area, so great was the amount of erosion accomplished during the Bajocian Denudation, that all the Ragstone-beds were removed, and the level of the former denudation was passed and obliterated. The limit of the strata removed by the Bajocian Denudation is rendered very apparent by the beds cut across being bored, or by the base of the immediate superincumbent deposit being slightly conglomeratic. This "bored-bed" has been frequently referred to in the preceding pages: in places the perforations are mainly the work of *Lithodomi*, but usually of annelids.

Once again the movement of subsidence predominated, and the Upper *Trigonia*-grit was deposited non-sequentially over the eroded and bored surfaces of the subjacent beds. The appended map (Plate X.) shows the area of the different beds upon which the Upper *Trigonia*-grit was laid down. This map will be found to differ somewhat from that given by Mr. S. S. Buckman in his paper on the "Bajocian and Contiguous Deposits in the North Cotteswolds: The Main Hill-Mass."* For the points wherein it differs some explanation is necessary. The Cowley-Wood section is the main factor determining these corrections. That section shows the Upper *Trigonia*-grit resting upon the *Buckmani*-grit. Only three-quarters-of-a-mile away, however, in the valley near Park House, Brimpsfield, the Upper *Trigonia*-grit rests upon the Upper Freestone—the latter rock exhibiting a bored surface. Thus the area where the former deposit rests immediately upon the Lower *Trigonia*-grit must be between the two exposures. This area is probably very restricted in the vicinity of Birdlip, the reasons for this conclusion being as follows. As a

* "Quart. Journ. Geol. Soc.", Vol. LIII. (1897), pl. XLVI.

result of the denudation at the close of the hemera *bradfordensis*, the Lower *Trigonia*-grit extended on to (see p. 141) the Freestone of the Birdlip anticline, as shown in the annexed (fig. 10) diagram; and then above

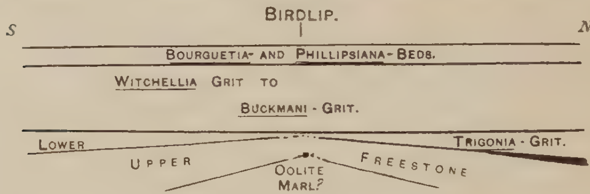


Fig 10.

were deposited the other various subdivisions of the Inferior Oolite Series—at least, from the *Buckmani*-grit to the *Phillipsiana*-beds. Now when the movements causing the Bajocian Denudation took place, the anticlinal flexure in the Birdlip area was repeated. There was then denudation of the anticline. Subsidence and the deposition of the Upper *Trigonia*-grit then terminated this erosion, so that the relationship of the Upper *Trigonia*-grit to the subjacent beds may be represented by the line A B (fig. 11). It will be easily understood,

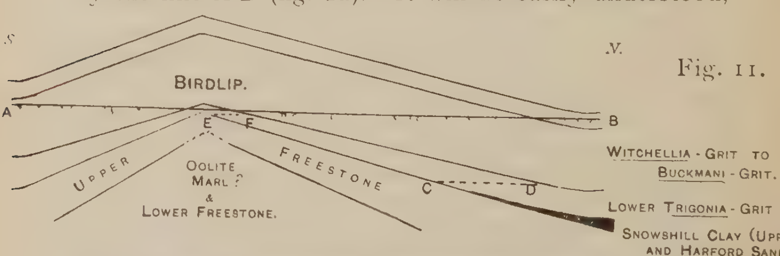


Fig. 11.

Diagram to show the relationship of the subdivisions of the Inferior Oolite Series after the Bajocian Denudation, the line A B representing the "Bored-bed."

therefore, that had the Lower *Trigonia*-grit been deposited equally over the whole of the Birdlip area, the geographical extent of the deposit in that area immediately below the Upper *Trigonia*-grit would have been represented by the dotted line C D, instead of that lettered E F.

In the field-road about a quarter-of-a-mile to the south-east of Combend, near Elkstone, the Upper *Trigonia*-grit is seen by the sections obtainable in several openings in the bank to be almost in contact with the freestone—pieces of which are seen lower down the road. Projecting from the north bank of the road are somewhat massive beds belonging to the Upper *Trigonia*-grit, containing *Rhynchonella angulina*, *Rhynchonella* cf. *subtetrahedra*, and *Terebratula globata*. Above is the *Clypeus*-grit, full of many varieties of *Terebratula globata*.*

For the areas of the different beds upon which the Upper *Trigonia*-grit rests in the Painswick area I have followed Mr. Buckman's map.

As regards the more exact location of the limits of the Gryphite-grit below the Upper *Trigonia*-grit. a section in a deeply-cut wheel-track about half-a-mile to the east of Colesbourne will assist. Ascending this lane from Monkscombe, there are seen, first of all, exposures of the freestone-beds, and then of the Lower *Trigonia*-grit, with a few *Gryphææ*. A little higher up the road there is typical Gryphite-grit, full of *Gryphæa* "*sublobata*," and having the top-bed covered with a layer of oysters ; while, as shown by pieces not found *in situ*—but only where they could have come from or very near indeed to the top—it is in places bored. The Upper *Trigonia*-grit succeeds, and yields the usual brachiopods. Somewhat unfossiliferous limestones separate it from the *Clypeus*-grit, which presents its well-known structure—creamy-white rubbly rock, with pisolite-spherules, and crowded with *Terebratula globata*, and near the top *Clypeus Ploti*. Passing into the adjoining field, immediately on the left, are hollows containing water, and excavated in the Fullers' Earth.

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* There appears to be a considerable thickness of White Limestone present here, and indications of the Fullers' Earth may be observed above. That this deposit also is of considerable thickness may be seen by noting where it first appears in the road-side, and where the spring bursts out which feeds the farm pond. The Fullers' Earth contains a limestone-bed full of crushed *Ostreæ*, as at Bull Bank Common near Miserden.

Gryphite-grit, with the Upper *Trigonia*-grit in close proximity, is seen half-a-mile to the east of Rendcombe Church.

It is now possible to define more correctly the limits of the *Witchellia*-grit. In company with Mr. S. S. Buckman, the writer examined the area immediately to the north-west of Shipton Oliffe. Bored pieces of Notgrove Freestone were obtained in the south-eastern portion of a large field, while pieces of bored rock resembling the *Witchellia*-grit were found in the north-west portion. At all events the bored freestone showed that the *Witchellia*-grit did not extend farther to the south-east. In the field immediately south of the road near the Cold-Comfort section the writer has picked up pieces of bored *Witchellia*-grit.

After the Bajocian Denudation there was a general movement of depression, and while the Upper *Trigonia*-grit and *Clypeus*-grit were being deposited, many forms of life flourished. A slight pause in the deposition of sediment seems to be indicated by the layer of *Ostreæ* on the top of the Upper *Trigonia*-grit ; otherwise, as far as is known at present, the Upper *Trigonia*- and *Clypeus*-grits and White Limestone were deposited during a period of comparative quiescence.

TABLE IV.—THE GREAT OOLITE SERIES.

	GEOLOGICAL SURVEY.	STRATIGRAPHICAL TERMS.	CHRONOLOGICAL TERMS (AFTER S. S. BUCKMAN).			RENEVIER'S CHRONOGRAPHIC SUBDIVISIONS.
			Hemera.	Age.	Epoch.	
Great Oolite Series.	Cornbrash.	Cornbrash.	*disci.*			
	Forest Marble and Bradford Clay.	Forest Marble.	*(coactatæ).**	Parkinsonian.	Stepheoceratidan.	Bathonian.
		Bradford Clay.				
	Great Oolite.	Kemble Beds.	*(maxillatæ).*†			
		Minchinhampton Beds ‡				
	Stonesfield Slate.	Stonesfield Slate.	*subcontracti.*			
	Fullers' Earth. (or Fullonian)	Fullers' Earth.				

* *Dictyothyris coarctata.* † *Terebratula maxillata.*

‡ Includes all the strata between the Stonesfield Slate and Kemble Beds.

Chapter VI.

THE GREAT OOLITE SERIES.

The term "Great Oolite Series" is here used to include all the stages from the Fullers' Earth to the Cornbrash inclusive. A reference to Table IV. may, at first sight, give the impression that the series is usually not of great thickness, the more so as the deposits are there stated to have been laid down during only four hemeræ. This, however, is not the case: locally, the thickness of the series appears to be about 300 feet. According to Mr. H. B. Woodward, the thickness of the Fullers' Earth "near Stroud and Cheltenham is about 70 or 80 feet, and it diminishes eastwards."* In the railway-cuttings in the Chedworth area are sections of the Great Oolite which "would lead to the conclusion that the total thickness of the formation does not exceed 120 feet."† With regard to the thickness of the Forest Marble "near Bath and Cirencester, [it is] about 100 feet thick; while in Oxfordshire it is rarely so much as 50 feet thick, and in some places not more than 12 or 15 feet."‡ The Cornbrash, however, is a thin deposit, "usually from 10 to 25 feet thick."§

Much detailed work is yet to be done in the Cheltenham district in connection with these rocks, and the difficulties attending the zoning of the deposits are numerous. This partly accounts for the few hemeral terms, but in comparison with the Lias and Inferior Oolite deposits the Great Oolite Series must have been a rapid accumulation, for there is great similarity in the fauna from the upper beds of the Inferior Oolite to the Cornbrash.

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* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 233.

† *Ibid.*, p. 291. ‡ *Ibid.*, p. 338. § *Ibid.*, p. 431.

THE FULLERS' EARTH.

This deposit rests upon the Inferior Oolite, but Mr. Buckman informs me* that no doubt in many cases what is called Inferior Oolite—the Chipping Norton Limestone, for instance—is of the same date as what is called Lower Fullers' Earth, and is only a calcareous modification; while it is probable that the Upper Fullers' Earth of the southern counties is really contemporaneous with the Great Oolite.

The term "Fuller's Earth" was applied by William Smith, in 1799, to certain marls and clays near Bath, which yield an important deposit of economic Fullers' Earth. In a recent memoir, published by the Geological Survey, the term "Fullonian" is suggested.†

Typically, the stage consists of blue and brown shales, clays, and marls, with occasional nodules of earthy limestone. In some localities there is present, towards the middle, beds of argillaceous limestone, known as Fullers' Earth Rock.

In the district under consideration the thickness of the deposit, according to former observers, varies considerably. Northwards of Sevenhampton and Eyeford, Prof. Hull remarked that it appeared to be dying out; while at Miserden, Witchell estimated its thickness at about 30 feet. At Pen Hill, near Colesbourne, Prof. Hull considered its thickness to be not less than 60 feet.

Fossils are not numerous in the Fullers' Earth of this district, but the officers of the Geological Survey have recorded a considerable number from somewhere near Upper Coberley.‡ A little crescentic-shaped oyster, rather pointed at the extremities, and known as *Ostrea acuminata*, is the most notable fossil. The economic Fullers' Earth of Bath has yielded to Messrs. Jones and Sherborn a large number of Ostracoda.§

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* *In litt.*, January 16th, 1904.

† "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 229.

‡ "Mem. Geol. Surv., 'The Geology of the Country around Cheltenham,'" p. 52.

§ "Proc. Bath Nat. Hist. Club," Vol. VI. (1888), p. 249.

Good sections of the Fullers' Earth are few, but, like the Upper Lias, the presence of this deposit can usually be detected by springs and marshes. Over the greater portion of the hill-country of the Cotteswolds it is of great importance in connection with the water supply, for without it a considerable area would be a waterless waste, without trees or inhabitants. It is interesting to note how villages and farms often have their sites determined by the supply of water retained or thrown off, and the soil is, moreover, well adapted for pasturage.

Most Cheltenham Botanists have heard of Fullers' Earth deposit in connection with the celebrated botanical oasis on Sevenhampton Common. At the head of the little valley running up into the Common there is a pretty example of what is known as "Differential Denudation." The soft Fullers' Earth has been so denuded that, first of all, there is the hollow excavated in the Inferior Oolite; then a well-defined terrace, caused by the denudation of the Fullers' Earth clay, bounded by a steep bank, caused by the harder rocks of the basement-beds of the Great Oolite Series.

The following section, now for the most part overgrown, is transcribed from the second edition of Murchison's "Geology of Cheltenham," and will show the position of the Fullers' Earth at this locality.

QUARRY ON SEVENHAMPTON COMMON.

	Ft.	Ins.
1. Soil	2	0
2. A yellow clay, of a somewhat soapy feel, very rich in fossil shells	6	0
3. Ragstone, similar to the Stonesfield Slate	0	4
4. Thin seam of soft stone, with *Ostrea acuminata* and small joints of Apiocrinites	0	3
5. Blue Marl	8	0
6. Ragstone	14	0
7. Stonesfield Slate	4	0
8. Fullers' Earth		

The soil at the bottom of the old excavations in this neighbourhood is often very damp, indicating the presence of an impervious deposit.

Above Brockhampton, several springs are thrown off the clay: one near Whitehill Farm (Hill Farm), and another three-quarters-of-a-mile south-east by east of the hamlet. The Fullers' Earth was once well exposed in the railway-cutting at Hampen, but this portion of the section is now almost obscured by vegetation. The villages of Shipton Oliffe and Compton Abdale derive their supply of water from the Fullers' Earth. A fine volume of water is thrown off at the latter village, and dashing from its artificial outlet runs along the side of the road below the Church, to find its way into the Coln, by way of the picturesque lateral valley of Cassey Compton. "Through Chedworth village a long railway-cutting was made in blue Fuller's Earth clay with beds of impure fullers' earth. On the south side of the tunnel the junction with the Great Oolite was again exposed, though not very clearly at the time of my [H. B. Woodward] visit, owing to slips. Beneath flaggy beds of oolite, and layers of hard concretionary and flaggy, sandy limestone (Stonesfield Slate), there occurred about 4 feet of clay with *Ostrea acuminata*, a hard band of white marl, and a considerable thickness of blue clay beneath. The entire thickness of the Fuller's Earth was shown further on, in a cutting west of the Barrow near the Roman Villa, at Chedworth. For the most part it consists of blue and grey clay, with 'race,' and occasional bands of earthy limestone towards the base: and near its junction with the Inferior Oolite it yielded *Ostrea acuminata*, *Avicula echinata*, *Homomya*, and *Pholadomya*. The thickness was about 50 feet."* A fault affecting the Fullers' Earth may be very plainly seen from the train when passing through the eighth cutting from Andoversford. South of Chedworth village there is another cutting showing the basement-beds of the Great Oolite (Stonesfield Slate)

* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 245.

and the upper portion of the Fullers' Earth. It is not difficult to see to what cause the village of Chedworth owes its site. Numerous springs burst out from the level of the Fullers' Earth, and give rise to a tributary of the Coln.

About a mile-and-a-quarter north by east of Colesbourne the clay is very fairly exposed in the sides of a large field-pond; and again, about half-a-mile to the north-east of this exposure there is another section in the sides of a small pond. At the latter place, the evidence for the fault depicted on the Geological Survey Map is very obvious, for, at a much higher level than the Fullers' Earth, and about a hundred yards to the north of the pond, there is an old quarry showing the Lower Freestone of the Inferior Oolite. Sections may frequently be obtained in the sides of ponds, for, as Prof. James Buckman has written, "This bed, too, is of great importance in an agricultural point of view, as on the hill-slopes meadows with their ponds, can be maintained in the 'skeins of clay,' as the farmer terms the Fuller's Earth band with which the otherwise brashy land is divided. . . . ."*

In the field-road a quarter-of-a-mile east of Rendcombe is rock-débris indicative of the Gryphite-grit, Upper *Trigonia*-grit, and *Clypeus*-grit, with an exposure of Fullers' Earth. In the valley between Bagendon and Combend there are no definite sections, but numerous springs indicate the position of this water-retaining deposit. If the stream be followed towards Combend, it will be seen to disappear near Moor Wood, having sunk through the porous beds of the Inferior Oolite. On the north side of this wood there is a stream which drains off the Fullers' Earth, and is forming a considerable deposit of travertine.

About three-eighths-of-a-mile south-south-east of Elkstone Church, near a barn, a spring bursts out; while above are clear indications of the Fullers' Earth,

* "Quart. Journ. Geol. Soc.," Vol. XIV. (1858), p. 111.

with a somewhat thick band of limestone full of *Ostrea acuminata*. The regular course of the Fullers' Earth in this area—except, of course, where disturbed by faults—has been commented upon by Prof. J. Buckman. who states that "on ascertaining the depths of wells at different points, a surface-section can be made out almost as accurate as with the theodolite ; and hence our sections for the most part enable us to determine along their whole lines the depths to water-bearing beds."*

In connection with the village of Birdlip, the same author has made some interesting observations, which may be given *in extenso*. "This water-bearing bed has been denuded from the Birdlip platform ; and hence the bar to the increase of dwellings in that picturesque locality, as the depth to the next water-bed—the Upper Lias, about 200 feet, is much too great for ordinary wells ; the dip, too, of the Fuller's Earth is from the place, and, besides, it is cut off by a deep ravine in Nettlecomb Bottom ; so that it offers too slight a drainage-area to render reservoirs for the water-supply of the place practicable."†

Around Needlehole, near Upper Coberley, some portions of the ground are very damp, and near Upper Coberley a spring of very pure water is thrown off.

Upon ascending the hill past the "Air Balloon," the Freestone and the Ragstone-beds are visible in Tuffley's Quarry, and in that on the other side of the road. A little higher up the Fullers' Earth gives rise to a small stream, which—flowing under the road—trickles down the face of the hill. Still higher up, however, the freestone of the Inferior Oolite is finely exposed in a large quarry, and the oblique lamination or false-bedding is most noticeable (Plate VIII). A fault is thus known to intervene, and the Fullers' Earth is let down on the north side.‡

* "Quart. Journ. Geol. Soc.," Vol. XIV. (1858), p. 111.

† *Ibid*. pp. 110, 111.

‡ *Vide* S. S. Buckman, "Cheltenham as a Holiday Resort" (1897), p. 9.

Clayey soil is to be noticed in the east bank of the road on the top of the hill about half-way between Birdlip and the Buckle-Wood Quarry. Brimpsfield, Caudle Green, Miserden, Winstone, and Duntisborne Abbotts are all built near or on the Fullers' Earth. On the right-hand side of the road from the last-named village to Miserden, and on Bull Bank Common, is exposed Fullers' Earth, and a band of limestone full of *Ostrea acuminata*. The best exposures at the present time (1904), however, are in the south bank of the lane from Calfway, at its junction with the road to Stroud. It is scarcely necessary to make any further remarks in connection with this deposit: its geographical distribution will be seen upon referring to the map which accompanies this work, and in the "field" springs and damp ground will indicate its presence.

THE GREAT OOLITE AND STONESFIELD SLATE.

The term "Great Oolite" was first used by William Smith, in 1812. The basement-beds of the Great Oolite are often extremely fissile, and such is especially the case at Stonesfield, near Blenheim. Accordingly, the term, "Stonesfield Slate" was considered an appropriate denomination for these deposits.

Very little is known about the Great Oolite Beds and Stonesfield Slate in the district under review, and, as Mr. H. B. Woodward has remarked, "North of Stratton [near Cirencester] there is considerable difficulty in tracing out the sequence of the beds." Lithically, the deposits vary somewhat, and in this district—except at certain horizons—fossils are scarce. At Minchinhampton Common, near Stroud, however, numbers of fossils have been collected, and many have been described by Morris and Lycett.* The fossils of the Great Oolite, taken as a

* "Monograph of the Mollusca from the Great Oolite," Pal. Soc. (1851-63); *vide* also "The Cotteswold Hills" (1857), p. 93; Proc. Cotteswold Nat. F.C.," Vol. I. (1853), p. 17; "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 278; "Geology of Stroud" (1882), p. 75. The type-specimen of *Nautilus subtruncatus* is in the Cheltenham College Museum: *vide* "Report Cheltenham College Nat. Hist. Soc." for 1898, p. 51.

whole, according to Prof. James Buckman, "more nearly conform to that which pertains to the shelly freestone and building-stone of the Inferior Oolite; and . . . it is curious to find how many shells are common to the two; however, in as far as hand-specimens of these two building rocks are concerned, we can usually find some distinctive fossils, the more common of which will be found in most of the species *Tancredia* of Lycett, *Pecten vagans*, *Lima cardiiformis*, *L. duplicata*, and *Natica*, *Purpura*, *Alaria*, *Melania*, and others of the univalve class, so many of which are not only distinctive, but of common occurrence."* The Brachiopoda "are few in species in the Great Oolite, and usually only occur in the occasional marly partings"; while, among the higher animals, "fishes may be referred to as presenting an important characteristic of the Freestones of the Great Oolite, when compared with the Inferior Oolite."

The fossil contents of the Stonesfield Slate are numerous, and include plants, insects, saurians, fish, and echinoderms. Cephalopods are very rare: they include *Perisphinctes gracilis*, *Belemnites* (*Belemnopsis*) *fusiformis* and *B. bessinus*. *Trigonia impressa*, however, is abundant in places, and locally may be used as a zonal fossil. The same may be said of *Rhynchonella concinna*, which occurs somewhat abundantly in the lower portion of the Great Oolite.

The highest beds of the Great Oolite are best exposed a little to the south of the area under review, in a quarry north of the fifteenth milestone east of Daglinworth, near Cirencester. The quarry is now (1903) disused, but the section is still very instructive.* Mr. H. B. Woodward noticed a shelly bed three feet below the top of the Dagham Stone, and recorded therefrom *Nautilus*, *Purpuroidea glabra*, *Pecten*, etc. It would appear that there is a non-sequence between beds 2 and 3 of the following section.

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* "Quart. Journ. Geol. Soc.," Vol. XIV. (1858), p. 115.

* *Vide* also "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 286.

QUARRY NEAR DAGLINWORTH, NEAR CIRENCESTER.

		Ft.	Ins.
Kemble Beds.	1. Brown, oolitic, shelly limestone; 2 to 3 feet	2	6
	2. Rubbly oolitic bed; *Ceromya excentrica*, *Homomya Vezelayi*, *Lima cardiiformis*, *Lucina bellona*, *Modiola*, *Pholadomya*, and *Terebratula maxillata*; the last-named fossil most abundant a few inches above bed 3	2	6
Minchinhampton Beds.	3. Hard bed of oolitic limestone; large oysters on the upper surface; 1 to 1½ feet	1	3
	4. Dagham Stone. Visible	9	0

The Kemble Beds were thus named on account of their development in the railway-cuttings near that station. Below are the Minchinhampton Beds. This term is used here to embrace all those deposits between the Kemble Beds and Stonesfield Slate. The most important subdivision of the Minchinhampton Beds is known as the Dagham Stone. It is characterized by irregular and ramifying tubiform cavities, and, as Mr. H. B. Woodward has written, "The most reasonable explanation seems to be that the soft calcareous mud was penetrated by burrowing organisms, which have left no other traces of their former presence in the now indurated deposit than the irregular lines of weakness caused by their burrows. These have been subsequently acted upon, both superficially and underground, by acidulated waters."*

On the east side of the main-road, on the Daglinworth Downs, the Minchinhampton Beds have been opened out.

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* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 286.

QUARRY ON DAGLINWORTH DOWNS.

		Ft.	Ins.
Minchinhampton Beds.	1. Dagham Stone. White oolitic limestone, much broken up by the weather: the top portion of the deposit, for a depth of fourteen inches below the surface, having tubiform cavities. In some parts of the rock are pisolite-looking spherules, *Lucina*, and a gasteropod	3	2
	2. More massive-bedded white oolite; visible	6	6

In the fields traversed by the path from Long Furlong Barn to the Rectory Farm,† Duntisborne Abbotts, many pieces of this Dagham Stone may be picked up.

Beds which occupy the stratigraphical position of the Stonesfield Slate are visible in a quarry at the cross-roads one-and-a-quarter miles east-south-east of Duntisborne Abbotts.

QUARRY NEAR DUNTISBORNE ABBOTTS.

	Ft.	Ins.
1.*a*. Limestone, white and brown, oolite-granules		
b. Limestone, brown, very slightly oolitic, cavernous; together..............	2	6
2. Brown and greenish-grey clay; 1 to 3 inches	0	2
3. Limestone, soft, yellowish; full of *Trigonia* aff. *pullus* and *Nerinæa* spp...	3	2
4. Brown and greenish-grey clay, replaced sometimes by hard limestone	1	0
5. Limestone, grey, in six beds, oolite-granules in regular lines, shelly: soft bands of greenish-grey stone separate these beds	7	0

† Not given on the present 1-inch Ordnance Survey Map.

The cavernous nature of the limestone distinguished as 1*b* may be explained by the decomposition of vegetable matter. Damp ground at a slightly lower level a little to the south indicates the Fullers' Earth, so that if the quarry were made a little deeper that deposit would be reached.

Continuing along the Ermine Street, a number of quarries will be noticed around Smith's Cross and Beech Pike. The excavations are in the lower portion of the Great Oolite. The stone worked at Smith's Cross is durable, and takes a good dressing. On the west side of the road is an old quarry showing oolitic limestones similar to those worked at Briary Copse; but below are more massive false-bedded rocks, very shelly, and containing *Ostrea Sowerbyi*, *Trigonia* sp., and *Limopsis oolitica*. About half-a-mile to the south of Elkstone is the following section in the basement-beds of the Great Oolite :—

Quarry near Elkstone.

	Ft.	Ins.
1. Yellowish, flaggy limestone, shelly; *Ostrea Sowerbyi*	1	8
2. Marl, with greyish-yellow bands of impure limestone, the whole crowded with *Ostrea Sowerbyi*	2	6
3. Reddish-brown, oolitic, shelly stone	0	8
4. Limestone, shelly, somewhat massive bed; *Ostrea*	3	9
5. Limestone, oolitic, soon shivers; visible . .	4	1

There is another section where *Ostrea Sowerbyi* is abundant, about a mile to the north of the above, at High Cross, in a very much faulted area.

Quarry at High Cross, Elkstone.

	Ft.	Ins.
1. Subsoil, clayey; full of *Ostrea Sowerbyi* . .		
2. Limestone	2	6
3. Grey, shelly marl, with oolite-granules	0	6
4. Pale-brown, slightly oolitic stone, shelly, flaggy at the base	1	10

	Ft.	Ins.
5. Similar stone	1	5
6. Brownish and greenish-grey clay, somewhat sandy streaks	1	1
7. Pale-yellow, slightly oolitic, shelly stone; visible	7	0

Strata near the base of the Great Oolite are quarried half-a-mile north of Stockwell; and again on the outlier the same distance to the north-west of Side—or Syde, as it is now locally spelt.

In the vicinity of Througham are several "slate" quarries. By the side of the road from Miserden to Througham, and about three-quarters-of-a-mile east-north-east of the latter hamlet, the Stonesfield Slate is worked.

QUARRY NEAR THROUGHAM.

	Ft.	Ins.
1. Marl, grey and yellowish-brown, with a band of rubbly, oolitic, shelly limestone	3	6
2. Limestone, greenish-grey, laminated, sandy, passing down into a hard grey, also slightly oolitic, and somewhat sandy limestone	2	3
3. Greenish-grey and brownish clay	0	6
4. Grey limestones, in places coarsely oolitic (especially top-bed): become non-oolitic and sandy towards the base of the section: weather into six or seven beds; about	8	0

On Througham Common, somewhat extensive quarrying operations have been carried on in order to obtain the Stonesfield or "Bisley Slates." "The Stonesfield Slate series is overlaid by 10 feet of current-bedded oolite, which is quarried for building-stone, for wall-stone, and for road metal."* Mr. Woodward also observes of this locality, "At Througham Field, where

* H. B. Woodward, "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 281.

Stonesfield Slate is worked, the blocks are improved by lying out all the Winter—the second or third frost breaks them up. Slabs, 6 feet square, or even more, are obtained. They furnish material for cow-sheds, mangers, bordering for gardens, and pitching for stables. There is not more than 18 inches of good tile-stone at this locality, but it occurs at slightly different horizons. I obtained some of the tools used at Througham Field and these are placed in the Museum of Practical Geology."* At the present time only one quarry is open, and this is distant about half-a-mile to the west-south-west of the hamlet.

QUARRY ON THROUGHAM HILL.

	Ft.	Ins.
1. Oolitic, flaggy limestone, only left in one part of the section; visible	2	3
2. Greenish-grey laminated sand-rock; 0 to 3 inches	0	1
3. Grey, slightly oolitic, flaggy limestone ..	0	9
4. Parting similar to 2	0	1
5. Limestone similar to 3	0	7
6. Grey, sandy rock, shelly; rain-spots ?, annelid-tracks	2	4
7. Sand deposit, yellowish-brown and greyish. In places indurated, so as to constitute a distinct bed	1	5
8. Hard, sandy limestone	0	10
9. More massive beds of fissile sandy strata. The weathering of the top-bed gives rise to a distinct and noticeable parting. *Trigonia impressa*. Visible	4	4

A section analogous to the above is seen at The Camp, a mile or so to the north; whilst at Bidfield (or Bitfield) Farm there is a quarry in the oolitic limestones which come immediately above the Stonesfield Slate, and constitute the lower portion of the Minchinhampton Beds.

* *Ibid.*, p. 485.

About a mile west-by-south of the Througham Quarry is another section in the Stonesfield Slate Beds—at Stancombe Cross.

QUARRY AT STANCOMBE CROSS, NEAR BISLEY.

	Ft.	Ins.
1. Dark-brown soil	2	0
2. Limestone, greyish-brown, shelly	1	1
3. Brownish, sandy stone, obliquely laminated, resting upon, and intimately connected with, a very	0	11
4. Shelly limestone, full of *Ostrea acuminata*	0	11
5. Brown and greenish-yellow arenaceous shale, clayey in places	0	9
6. Eight beds of very slightly oolitic stone, with shaly partings; visible	5	2

The nearest section of the Great Oolite to Cheltenham is on the west side of Hales Wood (near Chatcombe Wood), but the beds are not very fossiliferous: two species of *Ostrea* being the most abundant shells. Near Upper Coberley there is a quarry (in a field a quarter-of-a-mile east of the hamlet) showing 4 feet 8 inches of greyish oolitic stone. A somewhat marly bed, about 2 feet thick, yielding *Ostrea* cf. *acuminata*, *Ostrea Sowerbyi*, and *Lima cardiiformis*, separates this from oolitic limestones, with brown clayey partings, which are exposed for a depth of 9 feet.

The Stonesfield Slate of Sevenhampton Common, a mile or so north of Whittington, has been extensively worked in the past; and as the sections are comparatively near to Cheltenham, and the beds fossiliferous, it is natural that they should have received considerable attention.* Somewhat massive strata may be studied about half-a-mile west-by-north of White Hall Farm, but the only good section now open is situated a little to the left of the road from Whittington to Cleeve Hill, and near the first cottages.

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* "The Geology of Cheltenham" (1844), p. 17; "Proc. Geol. Soc.," Vol. I. (1834), p. 413; *Ibid.*, Vol. IV. (1844), p. 437; "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 294.

QUARRY ON SEVENHAMPTON COMMON.

	Ft.	Ins.
1. Rubble and bluish-grey and yellowish clay, *Nerinæa gracilis* and two other gasteropods, *Isastræa*, *Berenicea* cf. *verrucosa*, *Serpula*, *Ostrea acuminata*, *O. costata*, *O. Sowerbyi*, *Cypricardia*, *Clypeus*, *Anabacia complanata*,* *Pecten vagans*, *Terebratula* sp., *Rhynchonella concinna ;* visible	1	3
2. Limestone, yellowish, shelly ; *Nerinæa* spp. abundant, and *Ostrea acuminata :* 2 to 4 inches	0	3
3. Clay, brownish ; full of *Ostrea acuminata :* 2 to 3 inches	0	2
4. Limestone, similar to 2 ; same fossils : 2 to 3 inches	0	2
5. Marl, arenaceous, indurated in places, brownish streaks running in all directions ; *Ostrea acuminata*, *Pholadomya* aff. *deltoidea*, *Lima cardiiformis*, *Strophodus* (tooth) : $4\frac{1}{2}$ to $6\frac{1}{6}$ feet	5	4
6. Stonesfield Slate. Limestone, grey and greenish-grey, arenaceous. The middle portion of this deposit is a very hard blue-hearted rock, slightly oolitic, and yields the " slates." It contains plant-remains	4	6

Fullers' Earth. Greenish-yellow clay.

The beds exposed in this quarry are richly fossiliferous, and it is certainly the most interesting section of the basement-beds of the Great Oolite in the immediate neighbourhood of Cheltenham. The lower beds vary very considerably in thickness, even in this small area, as will be seen upon referring to the records of former investigators.

At Rowell Gate, about a mile to the east of Charlton Abbots, there is a quarry affording the following section

* *Anabacia complanata* (Defranc), = *A. orbulites*, (Lamouroux).

in strata, dipping at a considerable angle to the north-north-west: the beds from 1 to 4 corresponding to the similarly-numbered deposits in the preceding section.

Quarry at Rowell Gate.

	Ft.	Ins.
1. Clay, bluish-grey; visible about........	0	8
2. Limestone, yellowish; *Ostrea acuminata* abundant	0	3
3. Clay, greyish-brown	0	3
4. Limestone, yellowish; *Ostrea acuminata*	0	3
5. Clay, greyish, somewhat sandy	1	0
6. Limestone, greyish, very slightly oolitic; *Ostrea*, a coral	2	0
7. Clay, stone in places; 1 to 3 inches	0	2
8. Limestone, yellowish-white, very oolitic, obliquely laminated; *Ostrea*	4	3
9. Clay, absent in places; 0 to 5 inches	0	2
10. Limestone, oolitic, obliquely laminated; *Pecten*, *Modiola*, *Ostrea*, *Cypricardia*	5	9
11. Clay, dark-brown and greenish	0	4
12. Limestone, oolitic	1	10
13. Clay, or argillaceous stone; 1 to 3 inches	0	2
14. Limestone; visible	0	2

About a mile to the south of this section there is a quarry which shows one of the best exposures in the district at the present time (1904).

Quarry near Whitehill Farm, Hawling.

	Ft.	Ins.
1. Bluish-grey and yellowish clay; *Anabacia complanata*, *Cypricardia*, *Pholadomya*, *Pecten vagans*, *Rhynchonella concinna*, *Ostrea*		
2. Limestone, yellowish; full of *Ostrea acuminata*	0	4
3. Clay, brownish and bluish-grey; *Ostrea acuminata*	0	2
4. Limestone, yellowish; full of *Ostrea acuminata*	0	2

	Ft.	Ins.
5. Clayey marl, brownish and greyish; *Ostreæ*	1	1
6. Limestone, whitish, oolitic, weathers flaggy; shell fragments	6	0
7. Limestone, pinkish, shelly	0	4
8. Clay, greenish, with a thin stone band; 0 to 4 inches	0	2
9. Limestone, grey, brown oolite-granules; shelly in places	0	6
10. Clay, greenish	0	2
11. Limestone, grey, brown oolite-granules, splits up into thin, somewhat arenaceous layers in the upper part; *Ostreæ*; 8 to 10 inches............	0	9
12. Limestone, grey, almost non-oolitic; *Ostrea acuminata*	0	11
13. Limestone, grey	1	7
14. Limestone, grey, passing down into an extremely shelly stone, with a few brown oolite-granules; *Ostreæ*	2	0
15. Limestone, hard, grey, very shelly, a few brown oolite-granules	1	1
16. Limestone, hard, grey, brown oolite-granules, surface very conspicuously ripple-marked; *Ostreæ*; visible ..	0	4

Beds 7 and 8 are often absent, and then beds 6 and 9 are separated by a noticeable earthy deposit in which are a few water-worn pebbles. On the opposite side of the road to this quarry are old excavations in whitish oolitic limestone: presumably bed 6 of the above. Indications of the Fullers' Earth may be noticed in the same field, in the form of marshy ground. Similar whitish, oolitic, flaggy limestone has been worked a little to the south-south-west of Whitehill Farm, near the clump. There is another section one mile due east of Sevenhampton Church.

QUARRY NEAR SEVENHAMPTON.

	Ft.	Ins
1. Subsoil, and clay with *Rhynchonella concinna*, and *Terebratula* cf. *globata* .. 2. Rubble of two bands of yellowish limestone, full of *Ostrea acuminata*	4	1
3. Marl, clayey, indurated in places, bluish-grey and brown; *Ostrea*	3	0
4. Limestone, greyish-white, and sometimes oolitic; weathers into three or four beds in places	1	6
5. Marl, whitish, oolitic, stone in places, clay at top and base. That at the base is dark-blue, and full of shell fragments	0	6
6. Limestone in two layers. The upper band is hard, brownish-grey, and non-oolitic; it is bored in places; *Ostrea*, *Trigonia* (3 inches). The lower band is somewhat rubbly with marl in places; *Rhynchonella concinna*, *Terebratula* (5 inches)	0	8
7. Marl, brownish and greenish-brown; argillaceous stone in places	0	4
8. Limestone, brownish, somewhat fissile; 7 to 11 inches	0	9
9. Marl, light-brown, indurated in places, laminated	0	2
10. Limestone, greyish and brownish, fissile ..	0	4
11. Marl, parting; 1 to 3 inches	0	2
12. Limestone, greyish, oolitic, few fossils, certain beds fissile	7	0

A little under half-a-mile south-east by south, a quarry has been opened out in grey siliceous limestones—a very durable rock. The section shown in the railway-cutting at Hampen has been described by Mr. H. B. Woodward in the Geological Survey Memoir on "The Lower Oolitic Rocks of Britain,"* from which the following record is transcribed.

* Vol. IV. (1894), pp. 292, 293.

SECTION IN THE RAILWAY-CUTTING AT HAMPEN.

		Ft.	Ins.
White Limestone.	"White limestones; rubbly beds, with Gasteropods, *Ostrea*, *Terebratula maxillata* (smooth forms), and Corals	6	0
	Harder beds of white or creamy limestone, with scattered oolitic grains: *Lima cardiiformis*	5	0
	Alternations of pale grey, marly limestones, and somewhat fissile marls	5	0
	Pale earthy and finely oolitic limestone: bored	1	2
	Fissile, rubbly, and marly limestones	9	6
	Hard, fine-grained, white oolitic limestone: *Lucina*	2	2
	Fissile brown oolite	1	0
	Hard and compact white oolitic limestone	6	0
Marly Beds.	Bluish-grey and yellow oolitic marls, with *Ostrea*; and with two beds of grey shelly oolitic limestone: with lignite in the lower band	8	0
	Grey shaly and marly oolitic beds: *Ostrea Sowerbyi*	3	0
	Grey earthy and oolitic limestone: Gasteropod-bed, with Gasteropods and Lamellibranchs	1	0
	Grey earthy limestones, more or less oolitic: many Lamellibranchs . .	3	0
	Yellow and grey rubbly oolitic bed, with *Trigonia costata* ?, etc.	1	3
	Bluish-grey oolitic marl, indurated in places: *Ostrea Sowerbyi* abundant, and forms like *O. acuminata*	2	0
	Fissile and rubbly bluish-grey and yellow oolite, with marly and shaly bands; and curious tracks of animals, like those of the Forest Marble: *Modiola imbricata*, *Trigonia*, etc. These beds merge into those below	10	0

		Ft.	Ins.
Freestone.	Pale fine-grained oolite, false-bedded, with shelly and marly layers here and there, coarser oolite in places, and occasionally fissile beds. (= Taynton stone) about	30	0
Stonesfield Beds.	Yellowish marl, passing down into brown and blue shaly beds; with indurated and more or less concretionary layers of calcareous and micaceous sandstone (slaty beds): of which there are two prominent, though impersistent bands. Buff and grey sands occur irregularly, and tracks of animals may be observed on some of the thin flaggy layers. The slaty beds are more pronounced farther east....	10	0
	Bluish marly shales, with micaceous gritty layers; slaty at base	9	0
	Shaly beds..........................	2	0
	Band of bluish-grey obscurely oolitic and shelly limestone	0	4
Fullonian (Fuller's Earth.)	Bluish-grey marly shales, with bands of hard, pale marl, seen to depth of	10	0”

In the above section it will be observed that, occupying the stratigraphical position of what have, for convenience, been described as the Minchinhampton Beds, are strata distinguished as the Freestone, Marly Beds, and White Limestone. At the present time (1904) this railway-cutting affords the best section of the Great Oolite in the district under consideration.

About three-quarters-of-a-mile to the south-east of Shipton Oliffe, and on the south side of the main-road to Northleach, is a small quarry.

QUARRY NEAR SHIPTON OLIFFE.

	Ft.	Ins.
Subsoil.		
1. Marl, clayey, bluish-grey and yellowish, with thin layers of arenaceous limestone; chief layer $1\frac{1}{2}$ inches thick, and 8 inches above bed 2	1	10
2. Limestone, whitish, coarse oolite-granules; *Ostrea Sowerbyi*	2	1
3. Limestone, slightly oolitic, surface brown and waterworn, with annelid-tracks and plant-remains	0	6
4. Marl, soft, small oolite-granules, somewhat laminated, passing down into stone; visible	0	6

About a mile-and-a-half to the south-east again, near Compton Abdale, certain of the beds exposed are conglomeratic.

QUARRY NEAR COMPTON ABDALE.

	Ft.	Ins.
1. Clay and rubble; *Pholadomya*	1	10
2. Limestone, greyish and light-brown, and slightly oolitic, bored at top	2	4
3. Marl and rubbly stone	0	4
4. Limestone, light-brown, non-oolitic, contains pebbles, especially 9 inches below base of bed 3, and at the same horizon *Trigoniæ* are numerous; *Avicula*, *Lima cardiiformis*, *Ostrea*	2	8

In the neighbourhood of Chedworth there are many sections in the Great Oolite: those in the railway-cuttings have been described by Prof. A. Harker* and by Mr. H. B. Woodward.† A short distance to the north of Foss Cross Station is the Long (Stony) Furlong cutting, described by Prof. Harker "as the very finest section of the Great Oolite exposed in the whole of the Cotteswold

* "Proc. Cotteswold Nat. F.C.," Vol. X. (1892), pp., 82-93.
† "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV (1893); "The Lower Oolitic Rocks of England," p. 290.

area." At the present time (May, 1903) the stone is being quarried in this cutting for use in the construction of the barracks on Salisbury Plain.

At the entrance to Pinswell Farm, a mile-and-a-quarter west-north-west of Chedworth Church, or half-a-mile east-south-east of Woodlands Farm, the following beds may be studied :—

Quarry near Pinswell Farm.

	Ft.	Ins.
1. Subsoil, clayey ; numerous specimens of *Ostrea Sowerbyi*		
2. Whitish rubbly limestone : 14 inches above bed 3 is a layer full of several species of *Nerinæa*, *Natica Hulliana*	2	9
3. Three fairly massive beds of white limestone ; *Nerinæa* spp. *Astarte*, sea-urchin spines	3	9
4. Limestone : *a*. Upper 11 inches, whitish ; *Pinna* cf. *ampla*, *Myacites*. *b*. Lower 4 inches, brown and clayey	1	3

The beds in this section are somewhat fossiliferous. Bed 3 comprises strata, in ascending order, 1 foot 8 inches, 4 inches, 1 foot 3 inches, and 6 inches thick respectively : the 4-inch bed being a shaly parting. The shells recorded from bed 3 are from the uppermost 6 inches. About a mile to the south-west is a quarry in white oolitic limestones ; while similar beds are quarried three-quarters-of-a-mile east-north-east of Rendcombe Church.

Quarry near Rendcombe.

	Ft.	Ins.
1. Oolitic limestones, much broken up ; about	2	10
2. Marl, oolitic, clayey in places ; fragments of *Ostreæ*	0	8
3. White oolitic limestone ; about..........	9	0

East of North Cerney there are several quarries: one on the east side of the village is excavated in whitish oolitic limestones, while another at the cross-roads about half-a-mile still further east shows:—

Quarry east of North Cerney.

	Ft.	Ins.
1. Limestone, slightly oolitic, flaggy, much disturbed; about	2	0
2. Marl, greenish-grey, oolitic	0	8
3. Limestone, very hard, white, non-oolitic; *Lucina bellona*; slightly bored in places	2	9
4. Limestone, oolitic, yellowish-white; *Echinobrissus Woodwardi*, *Lucina bellona*, *Cypricardia nuculiformis*	6	6

The line of demarcation between beds 3 and 4 is most noticeable at a short distance away. The beds quarried on North Cerney Downs are as follows:—

Quarry on North Cerney Downs.

	Ft.	Ins.
1. Grey, oolitic, somewhat sandy limestone fragments mixed with sandy marl, much disturbed	3	0
2. Regularly bedded alternating layers of greenish-grey, sandy marl and stone	1	3
3. Whitish oolitic stone with *Lucina bellona*. The top stratum is hard and flinty	3	7

Bed 3 furnishes good flags from 3 to 4 inches thick. Probably the slight depression running between this section and the preceding one at the cross-roads indicates a line of fault.

Situated in a valley about three-quarters-of-a-mile in an easterly direction from North Cerney is the picturesque village of Calmsden, with its ancient cross, at the foot of which gushes forth a fine spring. It is somewhat difficult to decide from what deposit this water is thrown off: possibly the Fullers' Earth has been

reached in the natural excavation of this valley. Rendcombe Spring is to be seen near the barn about half-a-mile to the north-west, but the volume of water is not large even during a rainy period. This spring is reached by following an interesting valley, which shows considerable evidence of the former existence of a stream of no mean size. A quarry near the barn shows several clayey deposits.

Quarry at Rendcombe Springs.

	Ft.	Ins.
1. Clay and subsoil	1	9
2. Thin layer of brown sandy limestone	0	2
3. Clayey, arenaceous marl	0	7
4. Greyish and light-brown oolitic limestone: *Ostreæ* on upper surface	0	11
5. Clay, brown, grey and purplish, slightly arenaceous	1	0
6. Hard band of yellowish limestone, slightly oolitic, full of *Ostreæ*, sea-urchin spines	0	6
7. Greenish-grey rubbly marl, somewhat clayey near the top; *Ostreæ*	2	4
8. Light-brown, sandy limestone, non-oolitic. *Ostreæ* on surface when an intermittent layer of hard rubbly rock is absent; visible	0	7

At the junction of the roads immediately to the north of Calmsden there is a quarry, at the base of which is exposed a remarkable rock, somewhat of the appearance of Pea-grit, with a matrix of pure calcite. This rock passes upwards into a compact limestone, which has a peculiar conchoidal fracture.

Quarry at Calmsden.

	Ft.	Ins.
Subsoil	1	3
1. Grey, flaggy, oolitic limestone; about	1	0
2. Greenish-grey, oolitic marl	0	8
3. Flaggy, slightly oolitic, grey limestone	1	6
4. Greyish-green, marly, rubbly deposit	1	10
5. Peculiar white limestones, passing upwards into a hard flinty bed	4	0

At the southern end of this quarry beds 1 and 3 are separated by a very thin deposit of shaly matter. About three-quarters-of-a-mile south-by-west of Calmsden is a quarry showing much broken-up oolitic limestones, five feet thick, separated by a yellowish earthy deposit (1 inch) from four feet of oolitic limestones, current-bedded, and containing obscure plant-remains. The layers in which the plant-remains occur are somewhat sandy, and of a pale-brown tint. About 550 yards south-east by south several corals, including *Thamnastræa mammosa*, were picked up in the field; but there were no indications in the little quarry by the side of the Foss Way of a coral-bed. As will be seen upon referring to the geological map accompanying this work, the horizon at which the corals occur must be almost at the top of the Great Oolite, and near its junction with the Forest Marble, and therefore on the same stratigraphical horizon as the far-famed Fairford coral-bed.* White oolitic limestones were formerly quarried three-quarters-of-a-mile south of Aldgrove Barn, near Foss Cross.

The last section of the Great Oolite to notice is situated half-a-mile to the north of the hamlet of Woodmancote, near North Cerney.

QUARRY NEAR WOODMANCOTE.

	Ft.	Ins.
1. Limestone, slightly yellow, oolitic	2	4
2. Clay, greyish-blue and yellow	0	4
3. Limestone, white; *Lucina, Nerinæa*	3	2
4. Limestone, oolitic	2	9
5. Limestone, massive bed, but soon shivers	3	1

The above description of the Great Oolite Beds of this district is admittedly defective in certain points: especially as regards the exact correlation of the beds exposed in the various quarries. All the sections of any importance, however, have been noticed, and as the positions of all of them are shown exactly up on the

* *Vide* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 297.

map, it is hoped that this record may form the basis for future work. The quarries are mainly in the Stonesfield Slate and Minchinhampton Beds; the reason that there are so many in the Stonesfield Slate is, no doubt, due to the fact that those strata yield the best "slates." St. Matthew's and St. Mary's Churches, at Cheltenham, are roofed with such "slates."

THE FOREST MARBLE.

A little to the east of the country-town of Burford is Wychwood Forest. A century or more ago certain shelly oolitic limestones were worked here, and amongst other uses were employed for chimney-pieces in the houses in the neighbourhood. These limestones took a good polish, and for this reason William Smith adopted the term "Forest Marble" for the beds in 1799.

Between the Great Oolite and Forest Marble should come the Bradford Clay,* but in the district under consideration there are no definite indications of its presence. Consequently, there is considerable difficulty in fixing a definite boundary between the Great Oolite and Forest Marble. The most instructive section of the Forest Marble in this district is at Long Furlong,† near Foss Cross Station, and a little to the south of the hamlet.

Section near Foss Cross.

	Ft.	Ins.
1. Rubble of hard, bluish, shelly limestone; *Ostrea Sowerbyi*....................		
2. Bluish-grey clay; visible	1	3
3. Clayey, laminated marl, with thin courses of blue and brown, oolitic, very shelly, limestone; *Ostrea Sowerbyi* most abundant, *Terebratula* of an elongate *maxillata*-type	1	2
4. Hard limestone, oolitic, pinkish-brown; visible	0	4

* Thus called after the town of Bradford-on-Avon, where it is finely developed.

† Not marked on the present 1-inch Ordnance Survey Map, but is shown on the Geological Survey Map, Sheet 44.

In an old quarry in the adjoining field to the west is exposed bed 3 of the above section and about 5 feet of of hard oolitic limestones. The shaly beds of 3 are crowded with specimens of *Ostrea*, and a *Terebratula* of a *maxillata*-type is not uncommon, but the latter are not well preserved. The bluish limestone, of which fragments were noticed in the subsoil of the above section, is the typical Forest Marble. Pieces of such rock may be seen in the sides of the Foss Way half-a-mile east-south-east of Aldgrove (Allgrove) Barn; and again just over half-a-mile to the south of the same locality. Prof. A. Harker has described the sections on the railway.* The clay beds noticed at the base of the Forest Marble are important in connection with the water-supply. Near the cottages by the side of the Foss Way east of Aldgrove Barn, is a large pond which is is fed mainly by land-springs; while Long Furlong also derives its supply off the clay, as is seen by the pond near the farm. In the field immediately to the east are several wells, which the writer was informed were about 23 feet deep, and had a water-level of 15 feet. A well is being sunk in the field to the west of the farm, and was commenced in the Forest Marble. From the Great Oolite rock which has been thrown out have been obtained *Echinobrissus Woodwardi*, *Cyprina islipensis* and *Nucula* sp.

With the record of the sections of the Forest Marble the description of the "solid" rocks in the area under consideration is completed. Concerning the historical geology of the epoch during which the Great Oolite Series was deposited, little is known. The Fullers' Earth is very thin in the Sevenhampton and Eyeford areas, and it is probable that the deposit of those parts was laid down at no great distance from a coast line, while the land-surface was clothed with a considerable growth of vegetation.

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* "Proc. Cotteswold Nat. F.C.", Vol. X. (1892), pp. 82-93.

In the Stonesfield Slate beds there is abundant evidence of the flora of the age, and the vertebrate-remains are by no means uncommon. The facts as yet obtained seem to indicate that the deposition of the Great Oolite was comparatively rapid; but still there were pene-contemporaneous erosions at times, as is shown by the occurrence of pebbles in beds exposed in certain quarries (*vide* p. 169), and also by some of the beds having their upper surfaces waterworn and covered with annelid-tracks. The Forest Marble "bears evidence of its deposition in shallow waters, under marine conditions . . . ."*

* *Vide* "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" Vol. IV. (1894), p. 341.

Chapter VII.

DENUDATION, RIVER-DEVELOPMENT, SUPERFICIAL DEPOSITS, AND SCENERY.

Introduction.—The term "denudation" is explanatory of the degradation of the land-surface by natural causes, whether they be marine or sub-aërial. The agents of sub-aërial denudation may be separated into two classes: first, those which exert their influence over the general surface of the country, such as rain, frost, and that more extended action which is known as weathering; and second, those which exert their influence along special lines, such as streams, rivers, and glaciers. The work done by the former class of agents may be termed *general denudation*, and by the latter, *special denudation*. Prof. C. Lloyd Morgan, F.R.S., in an interesting paper on "Sub-aërial denudation and the Avon Gorge," observes that the vertical contouring of a district "is due to the differential action of general and special denudation on rocks of various powers of resistance."* The results of sub-aërial denudation are widely different from those of marine: as Lord Avebury has remarked, the erosion of the coast is horizontal and leaves headlands, but that of the land-surface is vertical and leaves hills.

The *Superficial Deposits*, such as gravel and sand, are the products of denudation: hence it is impossible to treat thoroughly of the one without referring to the other. Moreover, the scenery of a district is also due to denudation, and particularly to that action known as *differential denudation*. Differential denudation may be defined as the collective action of the agencies of denudation upon rocks of various powers of resistance. In order

* "Proc. Bristol Nat. Soc.," New Series, Vol. IV., Pt. III. (1884-5), p. 176.

to really appreciate what denudation has accomplished in this district, it is perhaps best to take our stand upon one of the numerous promontories of the Cotteswold Range. What a view may be obtained from Shurdington Hill! The contrast of hill and vale is most marked, but in the twilight, when the outliers cast their lengthening shadows eastwards, it does not seem so difficult to grasp the idea that once they also were part of the Cotteswold Range. Once that must have been the case, and the Severn Vale had no existence. We must picture the Inferior Oolite extending westwards on to the ancient rocks of Herefordshire. And if the Great Oolite, Bradford Clay and Forest Marble, Cornbrash, Oxford Clay, Corallian Beds and Kimmeridge Clay, maintained the thicknesses of their present outcrops, it is highly probable that they also spread over this district.

The historical geology of the district subsequent to the time when the Forest Marble was deposited may now be briefly considered. "Of the western extension of the middle Jurassic strata," wrote Mr. A. J. Jukes-Browne, F.G.S., "we have no actual evidence beyond the fact that all the marine limestones thicken in that direction—a fact which must be taken as indicating an approach to a coast-line rather than as a proof of distance from it, for the limestones have evidently been chiefly formed from the débris of coral-reefs, shallow-water Molluscs, and Echinoderms. It is, in fact, highly probable that a shore-line fringed with coral-reefs ran at this time by the Forest of Dean, May Hill, and the Malvern range."* After the deposition of the Kimmeridge Clay there was an elevation of this district: the sea of the Portlandian Epoch lying to the south-east. At a later time the Purbeck Beds accumulated in a series of shallow lagoons, and as time went on the Lower Wealden Beds were deposited in the lake—considerably broadened by the subsidence—which was at length submerged beneath the waters of the returning sea. Still the movement of subsidence continued, and gradually the seas of the successive epochs

* "The Building of the British Isles," 2nd ed. (1892), p. 211.

of the Cretaceous Period crept towards this area, until at the close of the Chalk Epoch it was deeply submerged. But during the long period of time which elapsed since the district was elevated, and became dry land, at the close of the Kimmeridgian Epoch, until it was submerged in late Cretaceous times, a vast quantity of material was removed by sub-aërial denudation, assisted by marine action at the beginning of the elevation and during the subsidence. How much rock was removed during this terrestrial period it is, of course, impossible to say, but it is evident that it must have been very great. For, as the Chalk rests unconformably on the outcrops of various Jurassic rocks, it is probable that in the Severn Vale it rested directly on the outcrops of Lias and New Red Sandstone (Keuper Series), as it does in the south of England, and that implies denudation —prior to the deposition of the Chalk—of the Middle and Upper Jurassic strata. During the formation of the Chalk it would appear that little of England was above the level of the ocean, for, in addition to the great thickness of rock accumulated, it must be remembered that the Chalk is probably a deep sea deposit, as it is not formed at the present day in water of less than 400 or 500 fathoms. A gradual upheaval then took place, and this district was elevated above sea-level. Thus we see that not only were the strata now terminating in the Cotteswold escarpment once continuous across the vale, but that above them were other rocks, hundreds of feet thick, extending westwards.

River Development.—At the close of the Cretaceous Period, then, the district was upheaved, and the mode of upheaval was such that there was a great plain having a prevalent south-easterly dip, extending from the backbone of Wales to the western shore of the sea in which the Tertiary beds were laid down. The movement of upheaval predominated, and the result was that, as Tertiary times drew to a close, this large plain extended from Wales to and beyond the site now occupied by London, and bounded on the south by a range of hills: the

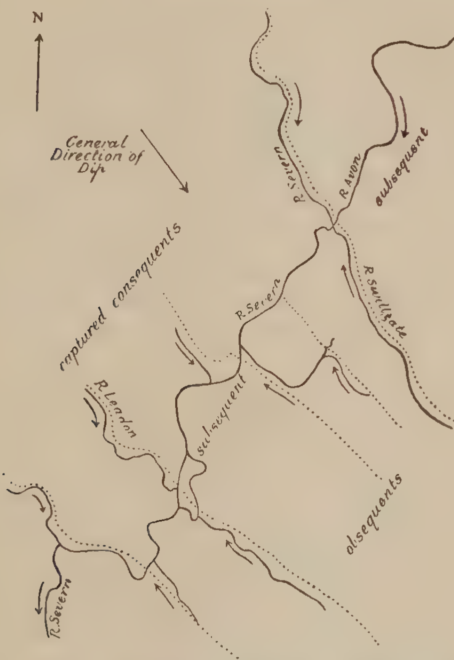
anticlines of the Mendips, of the vales of Pewsey and Kingsclere, and of the Weald. Now, the exact geologic structure of this plain whereon our present river-system had its origin is doubtful, but as soon as the Chalk was removed from this district, it must have been of very diverse stratal composition.

The main river of this system flowed eastwards along the north side of the above-mentioned range of hills. Into this west and east river flowed other rivers, coming mainly from the north-west—phenomena we should expect in consequence of the prevalent dip of the ground, and also of the rocks composing it. Smaller rivers would, of course, enter the main river on the right bank, draining the northern slopes of the hills constituting the *divide* or watershed between this Central River-system and that on the south side of those hills. The evidence for the supposition that the main streams, *consequents* as they are called,* flowed from north-west to south-east, is found in the run of certain large valleys, and in the peculiar direction of flow of certain tributaries of the Severn—especially in the area under consideration.

Fig. 12 is a sketch-map of the present arrangement of the Severn and its tributaries in the neighbourhood of Gloucester. It will be noticed that those on the right bank flow from north-west to south-east, while on the left bank the flow is from a south-easterly direction towards the north-west. In other words, these tributaries on the left bank run towards the Severn in a direction against the flow of that river. The view held is that the streams on the left bank still indicate the courses of the original consequents, and we shall shortly see what evidence there is for this supposition more than that afforded by this peculiar direction in the courses

* As Mr. S. S. Buckman has remarked, the terms such as *consequent*, etc., are awkward, because they clash with ordinary English words. In the Cotteswold district the term *dip-stream* could be used as a substitute for *consequent*, but in certain other areas it would be inapplicable.

FIG. 12.—SKETCH-MAP OF THE PRESENT ARRANGEMENT OF THE SEVERN AND ITS TRIBUTARIES NEAR GLOUCESTER.



The dotted lines indicate the supposed courses of the original consequents. From the Ordnance Survey, 1 ft. – 4 miles. (S. S. Buckman.)

of the streams. We may here consider two examples of these original consequents, and those given by Mr. T. S. Ellis, of Gloucester—who first called attention to the fact which has contributed so much to this fascinating theory of river-development in our district—will best serve our purpose. "If we could have it admitted," wrote Mr. Ellis, "that the trend of the country was originally to the east, before the present valley was formed at all,

following a slope as the Cotteswolds now dip, then one could imagine a stream flowing through the gap between Malvern and May Hills, along the line of the Leadon, and escaping over the present Cotteswolds at Witcombe, so first marking out one of the west to east streams, of which apparent signs remain."* Taking this example first, the course followed in our district would be approximately along the line of the Horsbere Brook, over the Cotteswold escarpment at Birdlip, and past Edgeworth. The little stream which now meanders in the picturesque valley between Nettlecombe and Edgeworth is but a feeble representative of the great river which once, probably, flowed along nearly the same course. Tracing this valley westwards from Nettlecombe, we see it gradually losing its distinctiveness ; but still it is possible to follow it almost up to the actual edge of the escarpment.

The probable course of another of these original consequents is indicated on Mr. Ellis's map, being along the course of the Severn to Tewkesbury, thence up the valley of the Swilgate† to Cheltenham, and up that of the Chelt to the Coln at Andoversford. Accordingly, we find that, supposing we are correct in our surmise that the peculiar direction in the course of the tributaries on the left bank of the Severn indicates the direction of the original consequents, by continuing in a south-easterly direction more evidence is to be obtained for our thesis ; and this evidence is, that there are large valleys—*through valleys* they are termed—trending in much the same direction. And yet another argument may be given in support of this theory. If we consider what is popularly termed the Chelt Valley—but, to be more correct, the pass from Cheltenham to Andoversford—a little more closely, we shall see that while the 600 feet contour-line has its apex directed eastwards, the 700 feet

* T. S. Ellis, "On Some Features in the Formation of the Severn Valley as seen near Gloucester," *School of Science Phil. Soc.* (1882), Gloucester.

† Or Swillgate.

contour-line has its narrowest part to the west, and its broadest to the east. What does this seem to show? In Mr. S. S. Buckman's words, it seems to indicate that this gap "could not have been cut out by the present river, the Chelt; but it could easily have been excavated by a river which, rising in the west, flowed eastward."* At Andoversford, the consequent which flowed through the Chelt Valley was joined by another river of considerable size, flowing down the Charlton Abbots Valley. Mention of this latter river brings us to consider the second phase in river-development. First we had the

FIG. 13.

Original consequent streams.

original consequents flowing over this district, with a direction from north-west to south-east (*vide* fig. 13). The ground intervening between them had to be drained, and thus streams were started more or less at right angles to the parent rivers; and since they worked along at right angles to the dip, the term *strike-stream* may be applied as an alternative for *subsequent*. As time went on, these subsequent streams invaded the drainage areas of the neighbouring consequents, and often effected a capture of one of those neighbouring consequents, with

* "Cheltenham as a Holiday Resort" (1897), p. 53. Cheltenham.

the result that there was a diversion of the water into whichever stream could give the quickest fall in the

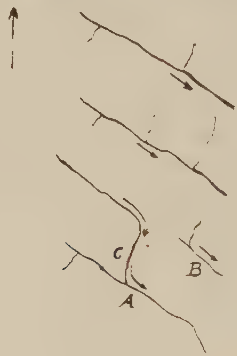


FIG. 14.

Development of subsequents.

shortest distance. Fig. 14 is intended to illustrate the development of subsequents. It would appear probable that the very marked valley which breaches the escarpment a little to the south-east of Hailes, near Winchcomb, and trends thence south-eastwards, past Guiting Power and Naunton, was once occupied by a somewhat important river; but that, eventually, a subsequent of the Severn-to-Coln River—as we may call the original consequent which flowed along the line of the Swilgate to Cheltenham, and thence through the Chelt Valley to the Coln at Andoversford—captured its head-waters by the development of a subsequent, with a direction now indicated by the Charlton Abbots Valley: the capture having been effected after the manner in which, diagramatically, the consequent A is represented to have captured the head-waters of the neighbouring consequent B by the development of the subsequent C (fig. 14). For a long period the original consequents, modified by the capturing of neighbouring consequents and the attendant further developments, continued to lower the level of the country. It may have been about this time that the

positions of the present outliers, such as Chosen, Robins' Wood and Bredon Hills were first determined.

A change in the river-system of Central England was then gradually produced by the Severn cutting its way backward. To what extent the rivers had developed when the invasion of the Severn took place cannot be stated at present: but as it captured the feeders of the Thames, these beheaded streams had to take their rise at some point farther to the south-east. Thus a divide or watershed was initiated between them and the Severn, and it had, approximately, a north-east and south-west trend. The north-west flank of this watershed would have to be drained, and in order to accomplish this, streams were started in the valleys excavated by the original consequents immediately to the east of the place of capture. As these streams worked back, the divide became more pronounced, until at the present day it constitutes a range of hills—the Cotteswolds. The Cotteswold escarpment is receding towards London; but the rate at which it is worn back is, of course, extremely slow. Now, as the direction of the original consequents was from north-west to south-east, it follows that the rivers initiated in those portions of the old valleys on the left bank of the Severn must also have a similar direction; but there would, naturally, be this difference, that the flow of the water in the new streams would be from south-east to north-west. The Swilgate was initiated in a portion of the valley excavated by the consequent Severn-to-Coln River, and the result is that the direction of flow of the former is from south-east to north-west—still preserving, as it were, the course of the original consequent. All the streams on the left bank of the Severn in this district are *anti-dip* streams—that is, they flow over the outcrop edges of the strata, and not with the dip. Such streams, however, are technically termed "obsequents."

A curve of the Chelt near Boddington is remarkable. Having a direction from south-east by west to north-west by north, between Cheltenham and Boddington, it turns

near the latter place to flow for a distance of one-and-a-quarter miles from north-east to south-west, and then about a quarter-of-a-mile from "The Barrow" it makes another almost right-angular turn. The explanation of this phenomenon may be that the portion between "The Barrow" and Boddington is a subsequent, developed by what may be called the Lower Chelt, whereby the waters of the Upper Chelt were diverted into the Lower. The Chelt can give a quicker fall for the water drained off the hills around Charlton Kings than the Swilgate, and the consequence is that the backward growth of the latter has been retarded by that of the Chelt, and the Chelt now continues to work its way backward up the pass from Cheltenham to Andoversford. We may here illustrate some of the above remarks on river capture by indicating a possible future capture. When the Chelt has worked its way back about another mile, it will effect the capture of the Coln, and will appropriate its waters. There is, however, one point to remember, and that is, that the Coln, if captured as indicated, would not then furnish its present supply of water, possibly by the difference of that volume supplied by the stream north of the Syreford Springs. The reason is that the Isbourne is also working back up the old subsequent valley of Charlton Abbots, and thus compelling the Coln to retreat, and obtaining the drainage once belonging to that stream. The Chelt, however, will eventually predominate over the Isbourne in the proportion of its drainage area, for the Chelt possesses that all-important factor in river-development —the advantage of giving water a quicker fall in a shorter distance than its rival.

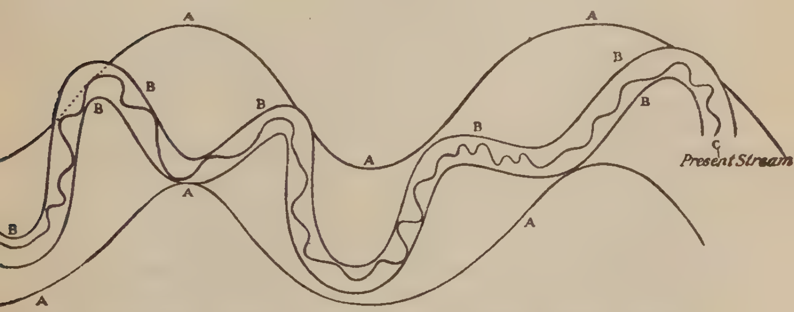
For the exact study of the evidence for the continued diminution of water in a river by means of the contours to be followed on the valley sides, and also of the meanderings of a stream, and the causes determining its course, the neighbourhoods of Sevenhampton and Withington are excellent and classic ground.

To Prof. W. M. Davis we are indebted for the theory of river-development, for although Mr. T. S. Ellis had,

some dozen years before, pointed out the fact which has become the basis of the theory in our district, still, until Prof. Davis's investigations, the subject did not attract much attention. The Sevenhampton and Withington areas were visited by Prof. Davis, in company with Mr. S. S. Buckman, and the results of these visits are chronicled by the latter in "Natural Science" for 1899, being on "The Development of Rivers, and Particularly the Genesis of the Severn."* Other notes are published by the same author in the "Proceedings" of the Cotteswold Naturalists' Field Club,† and more recently the subject has been referred to by Lord Avebury in his work on "The Scenery of England and Wales, and the Causes to which it is Due."

Three valleys, one inside the other, as represented in fig. 15, show the erosion accomplished by the Coln during its several phases of existence. "In the upper valley there are meanders of large curve, such as a river of large volume would make. In the lower valley the

Fig. 15.—Diagram of the Phenomena in the Coln Valley south of Andoversford.‡



* "Natural Science" (1899), pp. 273-289.

† "Proc. Cotteswold Nat. F.C.," Vol. XIII., Part III. (1900), pp. 175-190.

‡ Figs. 12, and 15 to 19 are reproduced by permission of the Cotteswold Naturalists' Field Club.

diminished river has been unable to follow the large curves, and it made two turns in each original meander. In the lowest or present valley the river is taking a wriggling course inside the smaller curves" (*vide* fig. 15). And these curves in the present little stream afford valuable information as regards the manner in which a stream determines its course. Perhaps it is hardly necessary to add that the laws which cause the little stream to impinge on its banks, and thereby give rise to miniature cliffs, are the same as those which cause the Severn to form such cliffs as those at The Mythe and Wainlode. To quote Mr. Buckman, the appended figs. 16, 17, and 18 "show the development of a stream from slight curves into pronounced meanders, which become greater as the river impinges more, first on the one bank and then on the other. In these figures, A A′ are the sides of the valley, B is the curving stream, and C C are the 'spurs' of the convex portions of the valley. These spurs tend to become more and more

FIG. 16.

Initiating curves.

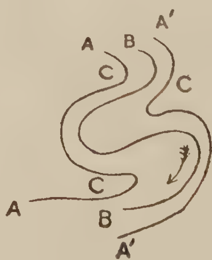


FIG. 17.

Pronounced curves and well-developed spurs.

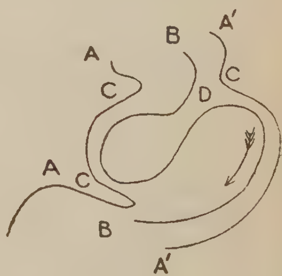


FIG. 18.

Considerable meanders with tendency to obliterate spurs.

worn away with the development of the meanders, on account of lateral encroachment of the stream—encroachment, that is, on the sides of the spurs; and it is the up-stream sides of the spurs which are most worn away. In time, when the curvature of the meanders becomes very great, the river straightens its course by cutting

through the narrow neck of the meander at D, as shown in fig. 19." An interesting example of the phenomenon, represented in fig. 18, is to be seen near Withington, and may be observed while passing in the train—the exact spot being half-a-mile south of the Frog Mill Inn.

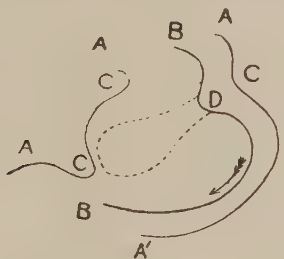


FIG. 19.
The meander neck severed.

And lastly, there are *dry valleys ;* that is, valleys which have no streams in them at the present time. On Cleeve Hill the south-westerly prolongation of the northernmost extension of the Postlip Valley is an example. There is little doubt that this was excavated by a stream given off by the Fullers' Earth when this deposit capped portions of the hill. When the clay was wholly removed, instead of the water being retained, it sank through the porous Inferior Oolite until it came to the next water-retaining bed. The Snowshill Clay is certainly a water-retaining bed, but on Cleeve Hill it is much disturbed, so that the next such bed is the Upper Lias—at least, that is the stratigraphical position of the next clay deposit, in descending order. A spring thrown off this clay supplies the wash-pool in the Postlip Valley. Thus the dry valley remains.

There are two very noticeable dry valleys which meet at the Seven Springs. When the Cotteswolds extended farther west, two tributaries met here, the larger flowing down Hartley Bottom, the other down the

conspicuous dry valley which trends northwards from the Springs, and may be traced across the Rifle Range.

At the present time the obsequents of the Severn are engaged in working their way back, eating into the escarpment, and playing an important part in its denudation. Thus we are brought by a consideration of river-development to investigate the superficial deposits.

Superficial Deposits.—Although the study of the Present is the key which unlocks the Past, nevertheless, the greater part of the history of the superficial deposits, such as gravel, sand, etc., which lie upon the "solid" rocks, remains to be written. Concerning the mode of formation, and the means by which the constituents of the superficial deposits were distributed, we may learn much from the study of what is going on around us at the present day.

Provisionally, the superficial deposits of sand and gravel in this neighbourhood may be classed under three headings; (1) débris of the Inferior Oolite found in the hill-country; (2) débris of the Inferior Oolite and Lias found near or on the flanks of the hills; and (3) quartzite pebbles occurring chiefly in the vale, but sometimes also on more elevated ground. The views held by geologists about the middle of the past century are well expressed in the second edition of Murchison's "Geology of Cheltenham." "It is difficult to explain satisfactorily the causes of that vast denuding action of which these beds of gravel are the relics, but the most probable assumption seems to be that the present land was elevated *slowly* out of the sea, and that during this gradual process the waves undermined, and the currents removed, vast masses of materials from our present valleys. To realize this supposition to our minds, we must adopt the view proposed by Mr. Murchison in his 'Silurian System,' and conceive that the vale of the Severn was once a strait of the sea; that Bredon, Dumbleton, and Churchdown Hills were islands, Leckhampton Hill a lofty cliff, and the beds of gravel at Cheltenham ancient shingle beaches.

MEANDERS OF THE RIVER COLN, NEAR CHEDWORTH.

(From a photograph by C. Upton.)

"The gravel near Cheltenham is wholly derived from the neighbourhood, but on the hills nearer the Severn, between Gloucester and Worcester, we find in the gravel many pebbles which have been brought from great distances, including quartz, granite, flints, slate rock, and many others. These *erratic* pebbles are supposed to have been brought into their present position by a current from the north, at the same time that the littoral waves were washing away the cliffs of the Cotteswold range, and deposited beds of oolitic shingle along their bases." Opinions have changed now: the theory of river-development has caused a reformation not only in its own branch of science, but also in that of the superficial deposits—especially in this district.

For the accumulations of the fragments of the Inferior Oolite found in the hill-country general denudation (*vide* p. 177) is mainly responsible; but some deposits are evidently the result of special denudation (*vide* p. 177). When dealing with the Lias we saw that the presence of the clay of the Upper Lias, between the Marlstone and the Inferior Oolite, gave rise to a gentle slope; while the sub-jacent and super-jacent rocks constituted prominent features. We should expect that Oolite would fall upon this slope, and that accumulations of such matter should occur. Prof. E. Hull, however, was inclined to adopt Prof. Andrew Ramsay's suggestion that the greater mass of this Oolite-débris, and also the slips which are so frequently to be seen on the hill-sides, were due to the agency of coast-ice in the Glacial Epoch.

Then there are gravels at a higher level, such as those which cap the promontory which juts out into the Postlip Valley, and in which there are several pits affording excellent sections. These gravels Prof. Hull considered the remains of sea-beaches, and observed that vestiges of such were to be seen along the whole line of the Cotteswolds. He further stated that this ancient beach could be known "first, by its position, which is always at or near the base of the oolitic cliff; secondly, by the waterworn and general smallness of the pebbles;

and thirdly, by the evident stratification of the whole."* A study of these deposits, however, does not favour this view. As W. C. Lucy wrote : "It is quite clear that no Gravel, of the soft, perishable kind derived from that part of the Cotteswold Hills, could have endured the variable changes arising from ice, frost, and snow, without being converted into Sand ; or, indeed, could have resisted the action of sea-water without being reduced to fine mud."

Near the ford in the upper part of the Hilcot Valley there is an accumulation of tumbled Oolite, much of which would be re-arranged or carried down stream if a larger river occupied the place of the present brook. Such seems to have been the case near the Syreford Springs, where there is an interesting section of somewhat contorted gravel, apparently arranged by river-action. The contortion may be due to pressure exerted by slipped rock, such as caps a portion of the section. We may say "river-action," for, as already pointed out, it is probable that a much greater volume of water once flowed down this valley.

On Charlton Common "gravel" is worked, but the constituents are the results of rock disintegrated by general denudation, and the spoil or waste shot over from the quarries above when they used to be worked. Other sections in débris of Inferior Oolite may be observed near the Air Balloon Inn, in the pit on the south side of Short Wood, and again on the north. In the village of Overbury, on the south side of Bredon Hill, a pit has been opened out in an accumulation of limestone fragments : mainly the product of the erosion of the valley in Overbury Park (*vide* p. 57). On the hill itself accumulations of shattered Oolite have frequently been cemented together into a kind of conglomerate by infiltrated carbonate of lime, and similar phenomena may be studied on Crane Hill (Oxenton), in the quarry facing south, and so conspicuous from Cleeve Cloud. So hard, indeed,

* "Mem. Geol. Surv., 'The Geology of the Country around Cheltenham'" (1857), p. 87.

does this conglomerate occasionally become that it has been employed for road-metal. The well-known "Bambury Stone," near the ruined tower on the summit of Bredon Hill, is a mass of this conglomerate; and the "King and Queen" rocks above Westmancote are examples of the same phenomenon.

When we come to consider the superficial deposits near, or on the flanks of the hills, we find the constituents to be débris of Lias and Oolite, with a light-brown quartzose sand—the last rock usually preponderating. It is not necessary to go far in order to study this deposit: indeed the best sections are in Charlton Kings. Quartzose sand is seen near the Holy Apostles' Church, in the south bank of the road; and frequently, with the fragments of the Liassic and Oolitic rocks in varying proportions, in excavations in our roads or streets. The sand-pit in Charlton Kings, known as Ryeworth or Cooper's Sand Hole, reveals a thick deposit of quartzose sand, with a little detritus of the Oolite and Lias: the thickness of the accumulation, according to Dr. T. Wright, being as much as 32 feet. When a trial-boring for the railway was made at Hopwood's Nurseries, 40 feet of sand was proved. Near Messrs. Webb's brick-kilns the deposit—almost pure sand—is well exposed, and it has been opened out in the villages of Prestbury and Bishop's Cleeve. About two-fifths of a mile north-east by east of Prestbury Church there is a fine section, showing, in ascending order, about 10 feet of gravel, composed of fragments of Oolite and Lias, with a little sand, then a dark clay band, 2 to 4 inches thick, succeeded by a deposit in which fine sand, pale greenish clay, and fragments of Oolite and Lias occur in more or less alternating layers. The writer is indebted to Mr. G. W. S. Brewer, F.G.S., for directing his attention to this interesting section: the derived fossils obtained from the gravel here by Mr. Brewer and himself being—*Cardinia* sp., *Cardinia attenuata*, *Arca Stricklandi*, *Pleuromya*, *Ceriopora*, *Isastræa tenuistriata*, *Acrosalenia*, *Rhynchonella subdecorata*, *Rhyn. subobsoleta*, *Rhyn.* aff. *cynica*,

Aulacothyris Blakei, *Terebratula fimbria*, *Ter.* cf. *globata*, *Belemnites* spp., *Dactylioceras* cf. *Braunianum*, *Liparoceras maculatum*, *Liparoceras arcigerens*, *Dactylioceras raquinianum*, *Dactylioceras Holandrei*, *Dactylioceras* cf. *angulatum*, *Amaltheus* cf. *coronatus*, *Amaltheus depressus?* and *Brasilina* cf. *Baylii*.

At Charlton Kings Station there is a large pit showing gravel similar to that worked near Prestbury. Many derived and rolled fossils may be collected, such as *Rhynchonella oolitica*, *Rhyn. Tatei*, *Terebratula fimbria*, *Gryphæa*, *Arca*, *Dactylioceras* cf. *Braunianum*, and numerous belemnites. The cuttings between this station and Leckhampton showed—during the widening of the line—a thick accumulation of the same materials: in one place sand predominated; in another fragments of Oolitic and Liassic limestones. The pit opposite the entrance to the Charlton Kings Laundry affords, perhaps, the best section of the sand-deposit in the district at the present time (1904). Then there is another pit to the south of Naunton Park Terrace, and fossils derived from the Lias and Oolite may be obtained. Near Southfield Farm a deposit, 4 feet thick, consisting mainly of débris of the freestone and Gryphite-grit, and yielding *Terebratula fimbria*, and *Gryphæa* "*sublobata*," is seen resting upon the clays of the Lower Lias. Gravel, similar to that worked at Charlton Kings Station and near Prestbury, is dug about a quarter-of-a-mile north-east by east of Leckhampton Church.

Occasionally, clay-bands are intercalated with the gravel and sand, and such is the case in a pit, now (1904) becoming overgrown, at Little Shurdington.

In the clay-pit at Brockworth a little Oolite-gravel may be noticed capping the clay, but as we approach Gloucester the deposit thickens. There are several pits in the neighbourhood of Barnwood: in one place sand predominates, in another Oolite-débris.

Exposures of similar deposits are numerous around Churchdown. Near the bridge at the station there was formerly a small pit, excavated mostly in sand, but there

GRAVEL AND SAND-PIT AT CHARLTON KINGS.

(From a photograph by F. L. Roberts.)

was some débris of Oolite, and more of Lias, containing belemnites and *Gryphææ*: the total thickness of the deposit exposed being about 8 feet. No gravel or sand, however, was turned out of the drain-excavations for the house near the signal-box at the station—the subsoil being dark-blue Lias clay. In the sides of the lane leading from the station towards the hill, sand is visible; and it is again well exposed in a pit near the new (1903) Wesleyan Chapel. In the road-side in the village of Staverton, opposite the turning to the Church, is an exposure of Oolite-gravel. In the village of Elmley Castle there is a disused pit showing about 5 feet of gravel, mainly derived from the rocks exposed on the north face of Bredon Hill. The writer collected here *Terebratula* sp., *Gryphæa*, *Dactylioceras* sp., and *Phlyseogrammoceras dispansum*. In the road-side opposite Little Comberton Church is exposed stratified débris of the Oolite and Lias, with a little sand; while another exposure in the same bank shows a deposit of sand, with an occasional quartzite pebble of small size. At Beckford the gravel has been extensively worked in the past, but now only a very small section is available. It shows chiefly Oolite-gravel, with a few quartz and quartzite pebbles. The writer has obtained here derived specimens of *Rhynchonella cynocephala*: while W. C. Lucy has recorded remains of *Rhinoceros*, *Elephas*, *Bos*, *Sus*, and *Cervus*; also a shell, identified by Mr. Glwyn Jefferys as *Lucina borealis*.

To sum up, then, the deposit grouped under heading (2) is found to consist essentially of quartzose sand, with irregular layers and patches of débris of Oolite and Lias, with many derived fossils. Now it is easy to see where the fragments of Oolite and Lias have come from; they are distinctly local: but there is no deposit in the hills around Cheltenham the denudation of which would produce so thick an accumulation of sand. The Bunter Sandstone of the Midlands is now usually regarded as its source, the rock having been transported thence mainly by river-action.

As we proceed to the west of a line running south from Bredon's Norton, and to the north of a line trending east and west through Elmley Castle, another constituent of the gravel appears in the form of pebbles of what has been commonly denominated "Northern Drift." In a pit to the north of the road from Cleeve Station to Stoke Orchard a few quartzite pebbles occur in the detritus of the Oolite and a little sand. *Gryphæa arcuata* is the chief derived fossil, some specimens being very much worn, others unrolled.

In the sections now to be described, "Northern Drift" preponderates. Concerning this "Northern Drift," W. C. Lucy wrote: "It is composed of Quartzose pebbles, long since shown by Sir R. Murchison to be derived from the conglomerate beds of the New Red Sandstone, Red Siliceous Sand, Lickey Quartz [Quartzite] Millstone Grit, Coal Measures, Igneous Rocks, Coarse Granite from Cumberland or Scotland, Silurian Slabs, with fossils, Old Red, Flint, Chalk, etc., etc."*

On the summit of Wainlode Hill (sometimes referred to as Sandhurst Hill), at an elevation of about 280 feet, several old pits in this gravel may be noticed. The constituents of the gravel here include a few flints. The fields around Southwick are covered with it, and thence it may be traced past Northway to Bredon. Here there are several pits, and in 1903 it was well exposed in the railway-cutting, its junction with the Lias clays being visible. The pits at Bredon are reached by going towards the village from the station, but turning up the first lane on the left, when they will be observed in a field also on the left. The constituents of the gravel here are mainly quartzite pebbles, with only very rarely a fragment of Oolite—the latter very little waterworn. According to Lucy, "At Bredon's Norton, in a field near the Church, called Gravel Hole, and which approaches nearer the hill, the N. D. [Northern Drift] and Oolite [gravel] join. This pit is at an elevation of 160 feet, and is the

* Proc. Cotteswold Nat. F.C.," Vol. V. (1872), p. 77.

highest point on Bredon at which I have met with Quartzose N. D. Sand."* This section is now obscured. Lucy also obtained from a pit opposite the fourth mile-stone on the road from Tewkesbury to Eckington, but which now (1903) affords a very indifferent section, a derived Chalk fossil—*Galerites subrotunda*.

South of Defford freshwater shells are said to have been found: the particular spot being 300 yards distant rom the Avon. Here also a "considerable number of bones have been procured."†

Mr. T. G. B. Lloyd has given the following details of a pit near Little Comberton, now filled in.‡ "The gravel-pit near Little Comberton remarkable for having yielded a very fine tusk of *Hippopotamus major*, now in the Worcester Museum, is situated at a distance of about a mile from the present river. A section in it was as follows :—

GRAVEL PIT NEAR LITTLE COMBERTON.

	Ft.	Ins.
Surface of ground.		
1. Light-coloured marly earth, with a few pebbles	2	0
2. Fine, quartzose flinty gravel, with seams of light-red sand	4	0
3. Light-red sand, with small pebbles (chiefly of flint)	0	3
4. Fine, quartzose, flinty gravel, and red sand	1	0
5. Whitish-coloured sand	0	6
6. Fine, quartzose flinty gravel, and red sand	2	6
Blue Lias clay.		
	10	3

In the bed No. 5 I found numerous specimens of freshwater shells enclosed in streaks of light-red clay. The surface of the basement clay was very uneven. In

* *Ibid.*, page 83.
† "Memoirs of H. F. Strickland," by Sir W. Jardine (1858), p. 99.
‡ "Quart. Journ. Geol. Soc.", Vol. XXVI. (1870), p. 213.

another part of the same pit, now filled in, the Rev. W. Parker, of Little Comberton, informed me he had found the lowest stratum composed of mud, containing fresh-water shells and remains of aquatic plants, lying on an uneven surface of blue Lias clay."

On the west bank of the Avon a gravel-pit at Twyning Green shows about 8 feet of gravel, similar to that at Bredon, with a few flints and a little Oolite-débris resting upon Lower-Lias clays. A very similar deposit may be studied in the pits on Shuthonger Common, near Tewkesbury. On the hill-flank opposite the south front of Pull Court, near Upton-on-Severn, is a pit showing :—

Pit near Pull Court, Upton-on-Severn.

	Ft.	Ins.
1. Reddish, quartzose sand................	3	2
2. Gravel, chiefly quartz pebbles, with little lumps of greenish marl............	0	8
3. Reddish-brown sand, current-bedded	2	10
4. Sand and gravel, with lumps of red marl ..	3	4
5. Red and yellow sand, somewhat compact, with a few small pebbles ; visible ..	2	0

At Tunnel Hill, near Upton-on-Severn, the main-road passes through a cutting, at the top of which "Northern Drift" is met with, at a height of about 100 feet above sea-level. At Upton-on-Severn, during the construction of the line, the Rev. W. S. Symonds found two molar teeth of *Elephas primigenius;* also *Turritellæ*, portion of a worn *Cardium*, and fragments of *Cyprina islandica.* The "Northern Drift" is exposed at Bengeworth, near Evesham, where a considerable number of bones of *Elephas* and other mammalia have been found.

The origin of the quartzite pebbles and the greater mass of the sand composing this deposit is, doubtless, the Bunter pebble-beds and sandstones of the Midlands. Dr. C. Callaway, in his Presidential Address to the Cotteswold Club in 1903, pointed out that the marine

shells found in the superficial deposits of the Lower Severn Valley were usually very fragmentary and much water-worn, and since they occurred in association with a great variety of pebbles derived from Shropshire rocks, it appeared highly probable that they had been washed out of the sands and gravels of Shrewsbury and Buildwas, and had been transferred by the river to the Lower Severn Valley. Dr. Callaway concluded that there were no proofs of the former existence of the sea in the Lower Severn Valley; and while, on the one hand, the fragments of marine shells were derived from the Salopian gravels, and therefore prove nothing of the age or origin of the deposits in which they are now found, on the other hand, the bones of mammals, recent and extinct, are *in situ*, and may be accepted as a test of the age of the gravels, since they are quite unworn. Hypothetically assuming the presence of land-ice in the Midlands in Glacial times, Dr. Callaway suggested that "The sequence of events would then be somewhat as follows. Ice-sheets moved southwards as far as the lower Severn Valley, and the northern margin of the Cotteswolds, bearing on their surface the huge boulders of granite and felsite found near Worcester and Evesham, as well as the accumulations of flints and quartzite pebbles spread so widely over Warwickshire and Worcestershire. On the retreat of the glaciers, atmospheric and fluviatile forces re-arranged and partly denuded the deposits formed during the Ice Age. Rain and streams carried down detritus to the rivers, and the rivers re-distributed it at lower levels."*

Alluvium.—The latest deposits of modern rivers or lakes, comprising gravel, sand, brickearth clay, mud, and silt, have been thus denominated. The Rev. W. S. Symonds wrote, "The race-courses of Worcester, Upton, Tewkesbury, and Gloucester, were formerly lakes forty or fifty feet in depth, into which rivers poured their sediment for ages, until the beds of the lakes became gradually silted up, and the rivers had to cut their

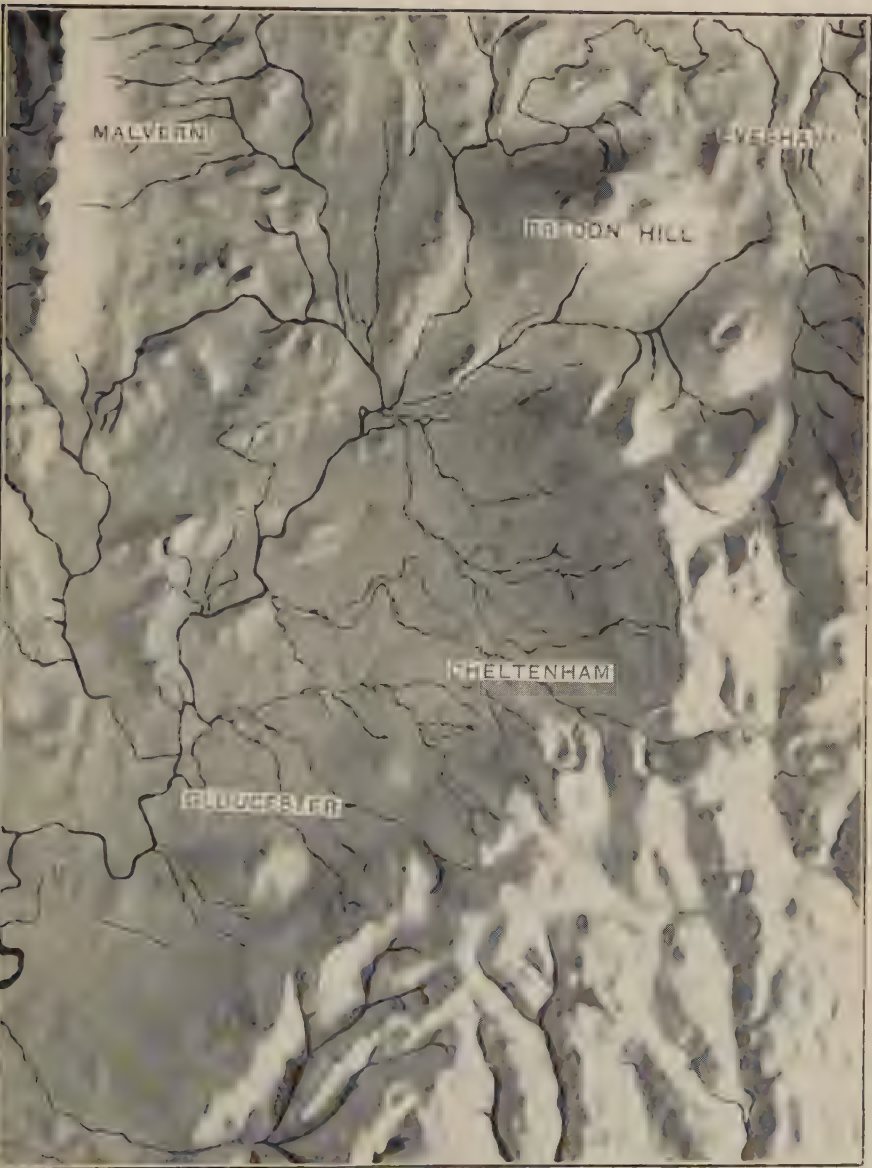
* "Proc. Cotteswold Nat. F.C.," Vol. XIV., Part III. (1903) p. 193.

channel through the lacustrine silt. During the excavations made for the Tewkesbury docks, the Alluvium of the Severn was excavated down to the old lacustrine silt. The Alluvium of the present river is between twenty and thirty feet thick. Below this was a stiff tenacious red clay, and below this, again, a black lacustrine silt, containing freshwater shells, some ancient pottery, and a fossilized horn of a red deer. The pottery was thirty feet, and the red deer's horn was thirty-seven feet and a half from the surface. Both were found in the lacustrine silt."†

In the newest deposit, to which the rivers are continually adding, shells were scarce in the sections examined by the writer—the pits near the ferry at the Lower Lode and at Upton-on-Severn. At the latter locality, however, the lowest deposit exposed is a blue clay, in which, the workmen informed the writer, a few shells were occasionally found. The lithic composition of the Alluvium bordering a river naturally depends mainly upon the nature of the rocks traversed higher up. Thus the Alluvium of the Chelt between The Leigh and Norton is extremely arenaceous owing to that stream having carried down sand derived from the deposits at Charlton Kings. The shells found in the Alluvium of this district are all of existing species.

Scenery.—If the reader has investigated for himself the rocks described in the preceding pages, when he comes again to stand on one of the lofty spurs of the Cotteswold Range, and to look over the vale, with its outliers and undulations, with the serrated ridge of the Malverns on the north-west, and the smooth slopes of the Cotteswolds stretching on either hand of him, he will more clearly realize the effects of denudation. Few parts of England offer a better field for studying these effects than the Cheltenham area.

† *Ibid.*, Vol. III. (1865), p. 37.



PHYSICAL MAP OF THE DISTRICT.

(From a Photograph of a portion of Miss A. F. Parkinson's Relief-Model of the District.)

Through the kindness of Miss A. F. Parkinson, of Cheltenham, I am able to reproduce the photograph of a portion of her excellent model. There at a glance may be studied cause and effect, and there also the contrast of hill and vale: the undulating character of the high ground, with its long bare rolling downs and deep and often dry sinuous valleys or combes; and the comparatively flat nature of the latter, but covered with many trees, and irrigated by many streams, and a noble river—the Severn. Similar features, plain and escarpment—such as we have in the district described—are repeated to the south south-east. From the high ground above Chedworth, and again above Cirencester, may be seen the gently sloping plain formed of the rocks of the Great Oolite Series and the Oxford Clay, whilst beyond lies the dim outline of the Chalk escarpment.

APPENDICES.

APPENDIX I.

LIST OF MINERALS FOUND IN THE CHELTENHAM DISTRICT.

Alunogen	*Upper Lias*, Churchdown.
Aragonite	*Lias*, Churchdown.
Baryto-Celestine	*Rhætic*, Wainlode Cliff ; Bourne Bank.
Blende	*Lias*, Pilley, Leckhampton ; Bengeworth.
Bole	*Lias*, Churchdown.
Calcite .. .. (The fibrous form is known as "beef.")	*Rhætic*, Wainlode Cliff ; Norton. *Lias*, Churchdown. *Inferior Oolite*, Cowley ; Colesbourne. *Great Oolite* (*Stonesfield Slate*), Sevenhampton Common.
Chalybite	*Middle Lias*, Churchdown.
Clay-ironstone	*Lias*, Churchdown.
Gypsum	*Upper Keuper Marls* (very rare), Wainlode Cliff. *Rhætic*, Norton.
Hematite	*Middle Lias*, Prinknash ; Shurdington Hill ; Bredon Hill.
Iron-pyrites	*Rhætic*, Wainlode Cliff ; Coomb Hill. *Lias*, Churchdown, etc.
Jasper	"Northern Drift," Bredon Station.
Limonite	*Lias*, Churchdown.
Marcasite	*Lias*, Churchdown.
Mica .. .. (Biotite and Muscovite.)	Disseminated throughout the *Rhætic* and *Liassic* rocks.
Quartz	*Rhætic*, Wainlode Cliff ; Norton ; Coomb Hill. *Inferior Oolite*, Huddingknoll Hill.
Rhodonite	*Middle Lias*, Gretton ; Churchdown.
Selenite	*Lias*, Churchdown and Alderton Hills ; Hucclecote ; Great Comberton. *Rhætic*, Wainlode Cliff ; Norton.
Stalactite	Often seen under railway-arches; also in fissures in the Inferior Oolite.
Travertine	Wainlode Cliff ; Churchdown ; Bagendon.

This list is the result of records made by the writer, and by the Rev. F. Smithe, M.A., LL.D., F.G.S. See "Proc. Cotteswold Nat. F.C.," vol. viii., p. 33.

APPENDIX II.

Lists of Fossils from the Cheltenham District.

NOTE.

The following lists of fossils have been compiled from many sources, and the writer has received much assistance from specialists. Great care has been exercised to have only reliable records, and although these lists represent the knowledge at present possessed concerning the fossils from this neighbourhood, there are many specimens which for want of names cannot be recorded. The lamellibranchs, ostracods, insects, annelids, and foraminifera, from the Liassic and Oolitic rocks in particular require attention.

APPENDIX II.

A.—Fossils from the Keuper Sandstone.* (Triassic System).

AMPHIBIA.

LABYRINTHODONTIA.	
Labyrinthodon sp.	Scutes and bones. "Bone-bed," Ripple.‡

PISCES.

ELASMOBRANCHII. (SELACHII.)	
Acrodus keuperinus (Murchison and Strickland)†	"Bone-bed," Ripple.
TELEOSTOMI.	
Ceratodus "*lævissimus*," Symonds ?	do. *Vide* "Monograph of the Sirenoid and Crossopterygian Ganoids," Pal. Soc. (1878), p. 32, pl. v., fig. 2.

CRUSTACEA.

PHYLLOPODA.	
Estheria minuta (Alberti) ..	Ripple.

PLANTÆ.

GYMNOSPERMÆ. CONIFERALES.	
Remains of conifers ?	Ripple.

B.—Fossils from the Rhætic (Jurassic System).

REPTILIA.

DINOSAURIA.	
Palæosaurus ? *Stricklandi*, Davis	Bone-bed (bed 15), Coomb Hill. Probably a derived specimen.
ICHTHYOPTERYGIA. (ICHTHYOSAURIA.)	
Ichthyosaurus sp.	Remains of. Bone-bed, Coomb Hill.

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* No fossils have as yet been recorded from the true Keuper Marls of this district.

† When an author's name is in brackets it indicates that the present generic name is not that under which the species was originally described.

‡ Reference is made to this interesting section in "The Geologist" for April, 1863, and rock-specimens may be studied in the Worcester Museum.

SAUROPTERYGIA. (PLESIOSAURIA.)	
Plesiosaurus sp.	*Vide* "Geology of Oxford" (1871), p. 106.
PISCES.	
Coprolites.	
Vertebræ.	
GANOIDEI.	
Gyrolepis Alberti, Agassiz ..	*G. tenuistriatus* included.
Saurichthys acuminatus, Agassiz	*S. apicalis* included.
ELASMOBRANCHII. (SELACHII.)	
Hybodus Delabechei, Charlesworth	Bone-bed.
—— *medius*, Agassiz ..	Bone-bed, Coomb Hill.
—— *minor*, Agassiz ..	Bone-bed, Wainlode Cliff.
Nemacanthus minor, Davis ..	See "Quart. Journ. Geol. Soc.," vol. xxxvii. (1881), p. 419.
—— *monilifer*, Agassiz ..	Bone-bed, Wainlode Cliff.
TELEOSTOMI.	
Ceratodus (tooth)	See "Old Stones" (1884), p. 97.
MOLLUSCA.	
LAMELLIBRANCHIATA. (PELECYPODA.)	
Anatina Suessi, Oppel.	
Avicula contorta, Portlock ..	Characteristic of the Lower Rhætic Stage.
Avicula sp.	*Pseudomonotis*-bed.
Cardium cloacinum, Quenstedt	Rare in this district.*
Gervillia præcursor, Quenstedt.	
Modiola minima, Sowerby.	
Modiola sp.	Bone-bed.
Myacites striato-granulata ? Moore	Fragment.
Myophoria sp.	
Ostrea fimbriata ? Moore ..	Fragment in bed 7, Wainlode Cliff.
Ostrea sp.	
Pecten valoniensis, Defranc.	
Placunopsis alpina (Winkler).	
Pleurophorus angulatus, Moore	See **pl. xiv., fig. 8**.
—— *elongatus*, Moore.	
Pleuromya crowcombeia (Moore)	Fragment of shell resembling this species.

* See "Quart. Journ. Geol. Soc.", Vol. LX. (1904), pp. 188, 207.

Protocardium rhæticum (Merian).	
Pseudomonotis decussata (Münster)	*Monotis.*
Pullastra (see *Schizodus*).	
Schizodus Ewaldi (Bornemann), and varieties	*Pullastra arenicola,* Strickland.
CRUSTACEA.	
MACROURA.	
Eryon sp.	*Coleia.* See "Fossil Insects" (1845), p. 65.
OSTRACODA.	
Darwinula liassica (Brodie) ..	*Cypris liassica,* Brodie.
—— *liassica* var. *major,* Jones.	
PHYLLOPODA.	
Estheria minuta var. *Brodieana,* Jones	*Cyclas* of Brodie. See **pl. xiv., figs. 4, 5.**
INSECTA.*	
ORTHOPTERA.	
Akicera Heeri, Giebel	*Blatta,* Brodie.
Diastatomma liasina (Strickland)	*Libellula Hopei,* Brodie.
PALÆODICTYOPTERA.	
Blattina sp.	
RHYNCHOTA.	
Cimex sp.	
DIPTERA.	
Asilus ignotus, Brodie	Figured, "Fossil Insects" (1845), pl. vii., fig. 19.
NEUROPTERA.	
Chauliodites minor, Blake ..	Figured, "The Yorkshire Lias" (1876), pl. xvi., fig. 6, and see p. 426: *vide* also "Fossil Insects," pl. x., figs. 7–9.
Hagla gracilis, Giebel.	
Orthophlebia communis, Westwood	Figured, "Fossil Insects," pl. viii., figs. 7–9.
—— *lata,* Giebel.	
Rapha liasina, Giebel	*Ephemera,* Brodie. See *Ibid.,* pl. x., fig. 14.

* Compiled mainly from "A History of the Fossil Insects in the Secondary Rocks of England," by the Rev. P. B. Brodie. See also C. G. Giebel, Fauna der Vorwelt (1856), Band 2, Abth. 1. The fossils recorded above are from the "Insect-limestone"; this stratum at Wainlode Cliff and Coomb Hill being now known as the *Pseudomonotis*-bed.

COLEOPTERA.	
Buprestites bractoides, Blake . .	Figured, "The Yorkshire Lias," pl. xvi., fig. 5, and see p.426.
Elater spp.	
Gyrinus natans, Brodie	Figured, "Fossil Insects," pl. vii., fig. 5.
Telephorus Haueri, Giebel.	
ANNELIDA.	
Annelid-tracks and burrows.*	
ECHINODERMATA.	
ECHINOIDEA.	
Pseudodiadema ?	Fragment of spine in bed 7, Coomb Hill (L. Richardson).
ACTINOZOA.	
Heterastræa rhætica, Tomes . .	Type-specimen from near Deerhurst. Figured in the "Quart. Journ. Geol. Soc.", vol. lix. (1903), p. 403, figs. 1, 2. See **pl. xiv., fig. 6.**
PLANTÆ.†	
I.—VASCULAR CRYPTOGAMS. (PTERIDOPHYTA.)	
EQUISETALES.	
Equisetites Munsteri, Sternberg	- *Equisetum Brodiei*, J. Buckman: "Quart Journ. Geol. Soc.", vol. vi. (1850), p. 414, fig. 1. [*Pseudomonotis*-bed ?] Strensham.
LYCOPODIALES.	
Lycopodites lanceolatus (Brodie)	Referred to in the text as *Naiadita lanceolata*. *Estheria*-bed. Abundant at Bourne Bank, near Defford. See "Fossil Insects," p. 93.
II.—GYMNOSPERMÆ.	
CYCADOPHYTA.	
Otozamites obtusus (Lindley and Hutton)	*Pseudomonotis*-bed.
CONIFERALES.	
Pagiophyllum peregrinum (Lindley and Hutton) . .	= *Cupressus* (?) *latifolia*, J. Buckman: "Quart. Journ. Geol. Soc.," vol. vi., p. 415, fig. 5.

* Markings probably due to annelids are to be observed on most of the sandstone-beds belonging to the Lower Rhætic Stage.

† In the preparation of this list the writer has received great assistance from Mr. A. C. Seward, F.R.S. See "Catalogue of the Mesozoic Plants in the Department of Geology, British Museum, 'The Jurassic Floras,'" pt. ii. (1904), pp. 9–21.

C.—Fossils from the Lias.

REPTILIA.

Ornithosauria.

Dimorphodon sp.	*communis*-zone,* Churchdown (*fide* Smithe); *spinati*, Dumbleton. *Pterodactylus.*

Crocodilia.

Steneosaurus sp.	Tooth, *communis*-zone (Smithe).

Ichthyopterygia.

(Ichthyosauria.)

Ichthyosaurus communis, Conybeare	Saurian-beds, Brockeridge Common.†
—— *intermedius*, Conybeare	do.
—— *tenuirostris*, Conybeare	do.
—— sp.	*Valdani* (collected J. W. Gray, F.G.S.).
—— sp.	*striati.*
Temnodontosaurus platyodon (Conybeare).	*oxynoti* or *raricostati.* Found near Christ Church, Cheltenham: the specimen is now in the Ladies' College Museum, Cheltenham.

Sauropterygia.

(Plesiosauria.)

Eretmosaurus rugosus (Owen)	Saurian-beds *Plesiosaurus.*
Plesiosaurus Hawkinsi, Owen	Saurian-beds.
Thaumatosaurus arcuatus (Owen)	Saurian-beds. *Plesiosaurus.*

PISCES.

Ganoidei.

Leptolepis concentricus, Egerton	"Fish-bed," Upper Lias.
—— *constrictus*, Egerton	do.
Pachycormus sp.	do.
Pholidophorus ?	Saurian-beds. Scales.
Tetragonolepis discus, Egerton	"Fish-bed," Upper Lias.

* *Pre-falciferi?*

† The Saurian-beds come below the *planorbis*-zone; they are of *pre-planorbis* date.

MOLLUSCA.

Cephalopoda.

Ammonoidea.*

Acanthopleuroceras carinatum (Quenstedt)	*Valdani.*
—— *gigas* (Quenstedt) ..	do.
—— *inflatum* (Quenstedt)	do.
—— *solare* (Quenstedt) ..	do.
—— *subarietiforme* (Futterer) ..	do.
—— *Valdani* (d'Orbigny)	do.
Ætomoceras Colesi (J. Buckman)..	*oxynoti.* Figured in the "Geology of Cheltenham," 2 ed., pl. xii., fig. 2, and described on p. 103.
—— *Guibali* (Reynès) ..	*oxynoti-raricostati.*
—— *lotharingus* (Reynès)	do.
—— *Scipionianum* (d'Orbigny) ..	*oxynoti.*
—— *Scipionis* (Reynès)..	*oxynoti-raricostati.*
Agassizoceras Gaudryi (Reynès)	*obtusi ?*
—— *Greenoughi* (Sowerby)	*oxynoti.*
—— *halecis* (J. Buckman)	*obtusi ?* Figured "Geology of Cheltenham," 2 ed., pl. xi., fig. 9, described p. 104.
—— *Sauzeanum* (d'Orbigny) ..	*Birchi.* From rock thrown out of the well for the pump in the village of Down Hatherley.
Amaltheus acutus (Sowerby)..	*margaritati.*
—— *coronatus* (Quenstedt)	do.
—— *depressus* (Quenstedt)	do.
—— *Engelhardti* (d'Orbigny) ..	do.
—— *margaritatus*, Montfort ..	do.
—— *nudus* (Quenstedt)..	*spinati ?*
—— *Stokesi* (Sowerby) ..	[*margaritati*, or *algoviani ?*]†
Arietites Turneri, Wright non Sowerby. ..	*Turneri.* = *Am. Brooki*, Reynès, non Sowerby.
—— *Fowleri* (J. Buckman)	*stellaris* or *oxynoti.* Figured "Geology of Cheltenham," 2 ed., pl. xii., fig. 7, described on p. 104.

* Drawn up by Mr. S. S. Buckman, F.G.S.

† Where hemeral names are placed in square brackets it is to denote the probable date of a species which has not been found *in situ*, or has been insufficiently recorded.

Arnioceras Bodleyi (J. Buckman)..	*Birchi ?* Figured, but not described "Geology of Cheltenham," 2 ed., pl. xi., fig. 7.
—— *nodulosum* (J. Buckman)..	*Birchi.* Figured "Geology of Cheltenham," 2 ed., pl. xii., fig. 6, described p. 105.
—— *semicostatum* (Young and Bird) ..	*Birchi.*
Asteroceras Brooki (Sowerby)	*obtusi.*
—— *cultellus* (J. Buckman)	*oxynoti.* Figured "Geology of Cheltenham," 2 ed., pl. xii., fig. 5; described on p. 103.
—— *Doris*, Reynès ..	*oxynoti-varicostati.*
—— *obtusum* (Sowerby)..	*obtusi.* Railway-cutting, Bredon Station.
—— *Smithi* (Sowerby) ..	*obtusi.*
—— *stellare* (Sowerby) ..	*stellaris.* Railway-cutting, Bredon Station.
Brodiceras sp.	[*variabilis.*] Bredon Hill (gravel-pit, Overbury).
Catulloceras Dumortieri (Thiollière)	[*Dumortieriæ.*] Beckford (gravel-pit).
Cheltonia accipitris (J. Buckman)	*oxynoti.* Figured "Geology of Cheltenham," 2 ed., pl. xi., fig. 6, described p. 102.
Cœloceras centaurus (d'Orbigny)	[*Valdani-striati.*]
Coroniceras sinemuriense (d'Orbigny) ?	*rotiformis.* = ? *Am. forficatus*, Strickland. Described "Geology of Cheltenham," 2 ed., p. 104.
—— *Bucklandi* (Sowerby)	*rotiformis.*
—— *latum*, Hyatt ..	do.
—— *rotiforme* (Sowerby)	do.
Cymbites globosus (Oppel) ..	*armati.*
Dactylioceras angulatum (Sowerby) ..	[*bifrontis.*] Gravel-pit, Prestbury.
—— *annulatum* (Sowerby)	*bifrontis.*
—— *commune* (Sowerby)	do.
—— *Holandrei* (Wright non d'Orbigny) ..	do.
—— *raquinianum* (d'Orbigny) ..	do.

Denckmannia bredonensis, S. Buckman	[*variabilis*.] Type-specimen found in the gravel-pit at Overbury. *Vide* "Quart. Journ. Geol. Soc.," vol. lix. (1903), pl. xxviii., fig. 1.
Deroceras armatum (Sowerby)	*armati*.
—— cf. *bispinatum*, Hug	*armati*.
—— *Davœi* (Sowerby) ..	*Valdani*.
Dumortieria sp.	[*Moorei*.] Gravel-pit, Overbury.
Echioceras finitimum (Blake)	*varicostati*, Wingmoor, Bishop's Cleeve. = "*Am Bonnardi*," "Geology of Cheltenham," 2 ed., p. 89.
—— *varicostatum* (Zieten)	*varicostati*. = "*Am Bonnardi*," "Geology of Cheltenham," 2 ed., p. 89.
Hammatoceras insigne (Schübler)	[*dispansi*.] "Light-coloured marly beds of Upper Lias, Sheepscombe" (Wright).
Harpoceras elegans (Sowerby)	*falciferi*. = "*Am. falcifer*," figured in the "Geology of Cheltenham," 2 ed., pl. xii. fig. 3.
—— *falciferum* (Sowerby)	*falciferi*. (*Fide* Oppel.)
Hildoceras hildensis (Young and Bird) ..	[*bifrontis*.] Gravel-pit, Prestbury.
—— *semipolitum*, S. Buckman ..	[*Lilli*.] Bredon Hill (gravel-pit, Overbury).
Lillia Lilli, Bayle	*Lilli*. Wistley Hill.
Liparoceras arcigerens (Phillips)	[*capricornus*.] Gravel-pit, Prestbury.
—— *Bechei* (Sowerby) ..	[*margaritati*.] *Am. nautiliformis*, J. Buckman, "Geology of Cheltenham," 2 ed., p. 105.
—— *capricornu* (Schlotheim) ..	*capricornus*. See **pl. xv., fig. 7.**
—— *cheltensis* (Murchison)	*striati*. Figured in the 1st ed. of the "Geology of Cheltenham," fig. 1, p. 20. = *Ægoceras striatum*, Wright non Reinecke.
—— *maculatum* (Young and Bird) ..	*capricornus*.
—— *Zieteni* (Quenstedt)	*striati*.
Lytoceras lineatum (Wright)..	*Valdani*.

Microceras biferum (Quenstedt) *oxynoti.*
—— *brevispina* (Sowerby) *armati.*
—— *densinodum* (Quenstedt) .. do.
—— *nudicosta* (Quenstedt) *oxynoti.*
—— *parvum* (Quenstedt) do.
—— *subplanicosta* (Oppel) *armati.*
Microderoceras Birchi (Sowerby) *Birchi.*
—— *rotundum* (Quenstedt) *armati.*
Oxynotoceras oxynotum (Quenstedt) .. .. .. *oxynoti.* = *Am. cultellus*, J. Buckman, figured in the "Geology of Cheltenham," pl. xii., fig. 4 (not fig. 5. See *Asteroceras cultellus*).
Paltopleuroceras hawskerense (Phillips) .. .. .. *spinati.*
—— *pseudocostatum* (Hyatt) do. See **pl. xiv., fig. 10.**
—— *pseudospinatum* (Hyatt) .. .. do.
—— *spinatum* (Bruguière) do.
Peronoceras cf. *Andreæ* (Simpson) .. .. .. *bifrontis.*
Phylloceras Calypso (d'Orbigny) [*Valdani* or *striati.*]
—— *heterophyllum* (Sowerby) .. *bifrontis.*
—— *Zetes* (d'Orbigny) .. [*margaritati.*]
Phylseogrammoceras dispansum (Lycett) .. .. [*dispansi.*] Bredon Hill (gravel-pit, Overbury).
Phricodoceras Taylori (Sowerby) [*Valdani.*] "Geology of Cheltenham," 2 ed., p. 91.
Polymorphites Bronni (Roemer) *varicostati.*
—— *erugatus* (Phillips) .. [*oxynoti.*] Figured "Geology of Cheltenham," 2 ed., pl. xi., fig. 8.
—— *mixtus* (Quenstedt) *varicostati.*
—— *polymorphus* (Quenstedt) .. do.
Pseudogrammoceras spp. .. Bredon Hill (gravel-pit, Overbury).
Psiloceras planorbis (Sowerby) *planorbis.*
Rhacoceras Boblayci (d'Orbigny) *Valdani-striati.* Figured in "Geology of Cheltenham," 2 ed., pl. xii., fig. 1*a* only.
—— *Ibex* (Quenstedt) .. *Valdani-striati.* = *Am. Boblayei*, figured in the "Geology of Cheltenham," 2 ed., pl. xii. fig. 1*b* only.
—— *Loscombei* (Sowerby) *Valdani-striati.*

Schlotheimia acuticosta (Strickland) ..	[*marmoreæ.*] Described in the "Geology of Cheltenham," 2 ed., p. 102. = ? *Am. catenatus*, d'Orbigny, non Sowerby.
—— *angulata* (Schlotheim)	*marmoreæ.*
—— *jugata*, S. Buckman	[*Birchi.*] = *Am. sulcatus*, figured in "Geology of Cheltenham," 2 ed., pl. xi., fig. 3 only.*
—— *lacunata* (J. Buckman)	*oxynoti* or *stellaris*. *Ibid.*, figs. 4, 5.
—— *subrotunda*, S. Buckman ..	[*Birchi.*] = *Am. sulcatus*. *Ibid.*, fig. 1 only.*
—— *sulcata* (J. Buckman)	[*Birchi.*] = *Am. sulcatus*. *Ibid.*, fig. 2 only; described on p. 105.
—— sp. (cf. *lacunoides*, Quenstedt) ..	[*oxynoti.*]
—— sp. (cf. *geyeri*, Hyatt)	[*stellaris* or *oxynoti.*]
Vermiceras Conybeari (Sowerby)	*rotiformis.*
—— *Lanndrioti* (d'Orbigny: Reynès)	*obtusi* or *stellaris.* Stoke Orchard; Gloucester docks.
Aptychus (various forms) ..	*communis*-zone (Smithe); and [" Fish-bed "] Dumbleton.

Belemnoidea.†

Belemnites aff. *aalensis*, Voltz	Top of Upper Lias, Firs-Brake section, Leckhampton Hill. Genus, *Megateuthis.*
—— *acuarius*, Schlotheim	Upper Lias. *Dactyloteuthis.* *B. tubularis*, Young and Bird.
—— *acutus*, Miller ..	*armati* to *Valdani.*
—— *apicicurvatus*, Blainville ..	*Valdani-striati.*
—— *breviformis*, Voltz ..	*spinati.*
—— *brevis*, Quenstedt ..	*spinati* (*fide* Smithe).
—— *Bruguierianus*, d'Orbigny ..	*communis*-zone [*pre-falciferi* ?].
—— *clavatus*, Schlotheim	*Valdani.* *Hastites.*
—— *compressus*, Stahl ..	*Valdani.*

* See also "Palaeontologia Universalis, Livraison 2," 1904.
† There are a large number of species which have not been identified as yet.

Belemnites elongatus, Sowerby	*Valdani*. Upper Lias (Sharman and Newton). *Belemnites*.
—— *longissimus*, Miller ..	*Valdani*.
—— *microstylus*, Phillips	"Fish-bed," Upper Lias.
—— *Milleri*, Phillips ..	*spinati*.
—— *oxyconus*, Quenstedt	*armati*.
—— *paxillosus*, Schlotheim	*spinati*.
—— aff. *paxillosus*, Schlotheim. ..	*armati*.
—— *pencillatus*, Sowerby	*Turneri*.
—— cf. *tripartitus*, Schlotheim ..	[*dispansi*.]
—— *Voltzi*, Phillips ..	Upper Lias, Cleeve Hill.
—— *vulgaris*, Young and Bird	*spinati*.
Belemnosepia	*communis*-zone (Smithe).

NAUTILOIDEA.

Nautilus astacoides, Young and Bird	[*Pre-falciferi ?*]
—— *intermedius*, Sowerby	*spinati* (Smithe).
—— *robustus*, Foord and Crick	*spinati*, Gretton, near Winchcomb.
—— *semistriatus*, d'Orbigny ..	[*obtusi ?*] Railway-cutting, Bredon.
—— *striatus*, Sowerby ..	[*raricostati* or *armati*.] Cleeve brick-fields (*fide* Buckman and Strickland).
—— aff. *striatus*, Sowerby	*Valdani* or *striati*.

GASTEROPODA.

Actæonina canariensis, Tate..	[*Valdani* or *striati ?*] "The Hewletts" (*fide* Tate).
—— *Dewalquei*, Oppel ..	[*oxynoti*.]
—— *ilminsterensis*, Moore	"Lower Lias, Cheltenham" (*fide* Hudleston and Wilson, "A Catalogue of British Jurassic Gasteropoda," 1892).
—— *marginata* (Simpson)	*armati*. = *Tornatella capricorni*, Tate. *Vide* "Quart. Journ. Geol. Soc.," vol. xxvi., fig. 18, and p. 405.
Alaria ŭnispinosa, Moore ..	Marlstone [*spinati*], Alderton Hill.

Amberleya capitanea, Goldfuss	*communis*-zone (Smithe).
—— *imbricata* (Sowerby)	*armati* to *spinati*. *Vide* "Mineral Conchology," Sowerby, pl. cclxxii., figs. 3 and 4. Type-specimen from "Clay near Cheltenham."
—— *selecta* (Chapuis and Dewalque) ..	Lower Lias (Phillips' "Geology of Oxford," p. 129).
Cerithium armatum, Münster	*Valdani*.
—— *camertonense*, Moore	*Valdani*.
—— *Huttoni*, Tate	[*spinati*.] Tate, "Geological Magazine," vol. viii., p. 7.
—— *Ibex*, Tate	*Valdani*. *Vide* "Quart. Journ. Geol. Soc.", vol. xxvi., pl. xxvi., fig. 8. Type-specimen in the Jermyn Street Museum. See **pl. xiv., fig 3.**
—— *varicostatum*, Tate ..	*varicostati*. Churchdown (Tate).
—— *Slatteri*, Tate	*Valdani*. Type-specimen at Jermyn Street Museum.
Chemnitzia Berthaudi, Dumortier ..	Lias (Hudleston and Wilson).
—— *Blainvillei* (Münster)	*Valdani*.
—— *liassica*, Quenstedt ..	do.
—— *undulata* (Benz) ..	do.
Cryptænia compressa (Sowerby)	[*spinati*.] Dumbleton (Hudleston and Wilson).
—— *expansa* (Sowerby) ..	*striati* to *spinati*.
—— *rotellæformis* (Dunker)	"Lower Lias near Cheltenham" (Hudleston and Wilson).
—— *solaroides* (Sowerby)	*spinati*.
Euomphalus? minutus (Schübler)	"Fish-bed," Upper Lias. = *Natica pilula*, Tate.
Exelissa numismalis, Tate ..	*Valdani*. See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 5, and p. 403.
Littorina biornata, Tate	*Valdani*. See *Ibid.*, fig. 17. and p. 404.
Monodonta modesta, Tate ..	Marlstone [*spinati*.] Churchdown (Tate).
Patella sabrina, Tate	"*angulata*-zone, Down Hatherley." *Vide* "Quart. Journ. Geol. Soc.," vol. xxvi., p. 402.
—— *Schmidti*, Dunker ..	"*angulata*-zone, Down Hatherley." *Ibid.*, vol. xxiii., p. 311.
Pitonnillus conicus, d'Orbigny	*spinati* (Smithe).

Pleurotomaria anglica (Sowerby)	*oxynoti* to *armati*.
—— *varicostata*, Tate ..	*varicostati*. Bredon. *Vide* the "Quart. Journ. Geol. Soc.," vol. xxvi., fig. 9, and p. 401.
Solarium inornatum, Tate ..	"Lower Lias, Hewletts Hill" (Hudleston and Wilson); but see Tate, "Geol. Mag.," vol. viii., p. 8. Type-specimen in the Jermyn Street Museum.
Turritella spp.	*Valdani* and *armati*.
Trochus acutus, Schlotheim ..	[*striati* ?] The Hewletts (Tate). See "Quart. Journ. Geol. Soc.," vol. xxxi., p. 505.
—— *Thetis*, Münster ..	*Valdani* and *armati* ?
Turbo admirandus, Tate ..	*Valdani*. See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 10, and p. 403. See pl. xiv., fig. 12. See **pl. xlv., fig. 9.** Allied forms in deposits of the hemerae *oxynoti*, *varicostati*, and *armati*.
—— *cryptænoides*, Tate	[*Valdani*.] See *Ibid*., p. 404.
—— *cyclostoma*, Benz ..	*spinati* (Smithe).
—— *lineatus*, Moore non Martin	*spinati*.

SCAPHOPODA.

Dentalium angulatum, J. Buckman ..	[*spinati*.] Described "Geology of Cheltenham," 2 ed., p. 101.
—— *elongatum*, Münster	*armati* to *capricornus*. See **pl. xiv., fig. 7.**
—— *giganteum*, Phillips ..	*capricornus*, Robins' Wood Hill.
—— aff. *limatulum*, Tate	*armati*. See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 1, p. 402. See **pl. xv., fig. 2.**
—— aff. *minimum*, Strickland ..	*Valdani*.
—— sp.	*Birchi*. Down Hatherley.

LAMELLIBRACHIATA.

(PELECYOPODA.)

Anatina numismalis, Tate ..	*armati* (late). See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 13, and p. 406.
Anomia numismalis, Quenstedt	*spinati*.
—— sp.	*striati*.

Arca elongata, J. Buckman ..	The exact horizon of this specimen seems doubtful: see "Geology of Cheltenham," 2 ed., and compare statements on pp. 74 and 96.
—— *numismalis*, Tate ..	*armati* (late). See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 3, and p. 406.
—— *Stricklandi*, Tate ..	*Valdani*, *striati*. See "Geology of Cheltenham," 2 ed., pl. x., fig. 6, and p. 96, where it is described as *Arca truncata*, J. Buckman; also "Q.J.G.S.," vol. xxvi., p. 407.
Arcomya elongata (Roemer) ..	*striati* = *Sanguinolaria striata*, J. Buckman, "Geology of Cheltenham," 2 ed., pl. x., fig. 10, and p. 100. See **pl. xix., figs. 2 *a*, *b*.**
Astarte cf. *obsoleta*, Dunker ..	*capricornus*.
—— *striato-sulcata*, Roemer	*capricornus* to *spinati*. = *A. amalthei*, Quenstedt.
—— sp.	*capricornus*.
—— sp.	do.
Avicula calva, Schlœnbach ..	*spinati* (*fide* Smithe).
—— *cygnipes* (Young and Bird)	*Ostrea*-beds (*pre-planorbis*).
—— *imbricata*, Moore ..	*spinati* (Smithe).
—— *inæquivalvis* (Sowerby)	*capricornus*, *spinati* (Smithe). *Oxytoma*. See **pl. xiv., fig. 11.**
—— *longiaxis*, J. Buckman ..	*striati*. See "Geology of Cheltenham," 2 ed., pl. x., fig. 2, and p. 97. Type-specimen in the Jermyn Street Mus.
—— *papyria* (Quenstedt)	*spinati*.
—— *substriata* (Münster)	*communis*-zone (Smithe).
—— sp.	*armati*.
Cardinia attenuata (Stutchbury)	*striati*. See **pl. xv., fig. 10.**
—— *concinna* (Stutchbury)	*spinati*.
—— *crassissima* (Sowerby)	Marlstone (Smithe).
—— *crassiuscula* (Sowerby)	*marmoreæ*.
—— *Listeri* (Sowerby) ..	*oxynoti* to *armati*.
—— *hybrida* (Sowerby) ..	*rotiformis*.
—— *ovalis* (Stutchbury)	*planorbis* to *gmuendensis* ?
—— sp.	*capricornus*. See **pl. xv. fig. 3.**
Cardita multicostata (Phillips)	*margaritati*.
Ceromya bombax (Quenstedt)	*spinati*.
—— *petricosa* (Simpson)	*spinati*. = *Isocardia liassica*, Moore: see page 51.

Cucullæa sp.	[*Moorei.*] Gravel-pit, Overbury.
Cypricardia intermedia, Moore	*capricornus.* See **pl. xiv., figs. 1***a,b.*
Gervillia crassa, J. Buckman	[*obtusi* or *stellaris* ?] See "Geology of Cheltenham," 2 ed., pl. x., fig. 9, and p. 98. Type-specimen in the Jermyn Street Museum.
—— aff. *fornicata*, Lycett	[*Moorei.*] Gravel-pit, Overbury.
—— *lævis*, J. Buckman..	*striati* and *capricornus.* See "Geology of Cheltenham," 2 ed., pl. x., fig. 8, and p. 98. Type-specimen in the Jermyn Street Museum. See **pl. xv., fig. 4.**
Goniomya heteropleura, Agassiz	*spinati.*
—— *hybrida* (Münster) ..	*capricornus.*
Gresslya donaciformis (Phillips)	*spinati.*
—— *galathea* (Agassiz) ..	*margaritati.*
—— *intermedia* (Simpson)	*spinati.*
—— *Seebachi*, Brauns ..	*spinati* (Smithe).
—— *striata*, Agassiz. ..	do.
Gryphæa arcuata (Lamarck), and varieties ..	*marmoreæ* to *Birchi.*
—— aff. *arcuata* (Lamarck)	*raricostati* and *armati.*
—— *cymbium* (Lamarck)	*capricornus* to *margaritati.*
—— *gigantea*, Sowerby ..	*spinati.*
Harpax Parkinsoni, Quenstedt	*spinati* (Smithe).
Hinnites tumidus (Zieten) ..	do.
—— *papyraceus* (Zieten)	[*Pre-falciferi ?*]
Hippopodium aff. *ovalis*, Moore	*capricornus.*
—— *ponderosum*, Sowerby	*armati.*
—— spp.	*striati ; Turneri.*
Inoceramus dubius, Sowerby	[*Pre-falciferi ?*]
—— *incurvatus*, Tate ..	*capricornus.* See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., figs. 2 and 2*a*, and p. 407.
—— *substriatus*, Münster	*capricornus.*
—— *ventricosus* (Sowerby)	*Valdani* and *striati.*
Leda galathea, d'Orbigny ..	*communis*-zone, *spinati* (Smithe)
—— *graphica*, Tate ..	*capricornus.* See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 12, and p. 407. See **pl. xv., fig. 11.** *Nuculana.*
—— *minor* (Simpson) ..	*communis*-zone.
—— *ovum* (Sowerby) ..	[*Pre-falciferi* ?]
—— *subovalis* (Goldfuss)	*spinati.*
—— *Zieteni*, Brauns ..	*armati.*

Lima gigantea (Sowerby) ..	*planorbis* to *gmuendensis*.
—— *pectinoides* (Sowerby)	*gmuendensis* ?
—— *scabricula*, Tate ..	*armati* (late). See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 15, and
—— *succinta* (Schlotheim)	*capricornus* = *L. antiquata*, Sowerby.
—— *toarcensis*, Deslongchamps	*communis*-zone (Smithe).
—— sp.	*Birchi*.
Limea acuticosta, Münster ..	*spinati*.
Lucina limbata, Terquem and Piette	*rotiformis* ?
Macrodon Buckmani (G. F. Richardson) ..	*striati*, *capricornus*. See **pl. xv., fig. 9.**
—— *hettangiensis* (Terquem) ..	*Ostrea*-beds.
—— *intermedius* (Simpson)	*capricornus*. See **pl. xiv., figs. 2** *a*, *b*.
—— *pulchellus*, Tate ..	*armati*.
Modiola cf. *compressa* (Goldfuss)	[*Pre-falciferi* ?]
—— *minima*, Sowerby ..	*Ostrea*-beds.
—— *numismalis*, Oppel ..	*spinati*.
—— *scalprum*, Sowerby ..	*capricornus*, *spinati*.
—— aff. *scalprum* Sowerby	*striati*. See **pl. xv., fig. 6**.
—— *subcancellata*, Buvignier ..	*spinati*.
—— cf. *hillanoides* (Chapuis and Dewalque)	*planorbis*.
Myoconcha decorata (Münster)	*spinati* (Smithe).
Nucula claviformis, Sowerby	[*Pre-falciferi* ?]
—— *cordata*, Goldfuss ..	*Valdani*.
—— *Hammeri*, Defranc ..	[*Pre-falciferi* ?]
—— *ungulella*, Tate ..	*Valdani*. See "Quart. Journ. Geol. Soc.," vol. xxvi., pl. xxvi., fig. 11, and p. 407.
Opis carusensis, d'Orbigny ..	*spinati* (Smithe).
—— *Deslongchampsi*, Tate	*spinati*
Ostrea irregularis, Münster ..	*marmoreæ*.
—— *liassica*, Strickland	*Ostrea*-beds. Described in "Geology of Cheltenham," 2 ed., p. 99.
—— *sportella*, Dumortier	*spinati*.
—— *submargaritacea*, Brauns	do.
Pecten æqualis, Quenstedt ..	*oxynoti*.
—— *æquivalis*, Sowerby	*spinati*. *Pseudopecten*.

Pecten cf. *calvus*, Goldfuss ..	*spinati*.
—— *lunularis*, Roemer ..	*spinati* (Smithe).
—— aff. *priscus*, Schlotheim ..	*striati*.
—— *pumilus*, Lamarck ..	*spinati* (Smithe).
—— *substriatus*, Roemer	do.
—— cf. *textorius*, Schlotheim ..	*Birchi*.
—— *textilis*, Münster ..	*marmoreæ*.
—— sp.	*armati* (late)
Pholadomya ambiqua (Sowerby)	*spinati* (Smithe).
—— *decorata*, Zieten ..	do.
—— *Hausmanni*, Münster	*capricornus*.
Pinna Hartmanni, Zieten ..	*planorbis*.
Placunopsis liassica, Smithe	*spinati*.
Pleuromya costata (Young and Bird)	*capricornus*.
—— *crowcombeia* (Moore)	*Ostrea*-beds.
—— aff. *granata* (Simpson)	*margaritati*.
—— cf. *ovata* (Roemer) ..	*armati*.
Plicatula lævigata, d'Orbigny	*spinati* (Smithe). See "Proc. Cotteswold Nat. F.C.," vol. vi. (1877), pp. 341–348, and plate.
—— *sarcinula*, Münster ..	do. See Ibid., p. 403.
—— *spinosa*, Sowerby ..	*spinati*, *margaritati*.
—— spp.	*armati*, *Valdani*, *striati*.
Posidonomya Bronni, Voltz ..	[*Pre-falciferi* ?]
Protocardium truncatum (Sowerby) ..	*capricornus* to *spinati*.
—— *oxynoti* (Quenstedt)	*armati*.
Pseudomonotis decussata (Münster) ..	*Ostrea*-beds.
Tellina sp.	*spinati*.
Unicardium cardioides (Phillips)	*rotiformis*, *armati*, *striati*.
—— *subglobosum*, Tate ..	*spinati*. = *U. globosum*, Moore.

BRACHIOPODA.*

Aulacothyris resupinata (Sowerby) ..	*spinati*.
—— *florella* (d'Orbigny)	*spinati*.
—— sp.	[*Dumortieriæ*.] Robins' Wood Hill.
Cincta Lycetti (Davidson) ..	*communis*-zone (*fide* Smithe).
—— cf. *numismalis* (Lamarck) ..	*oxynoti* and *armati*.

* In the preparation of this list the writer has received much assistance from Mr. S. S. Buckman.

Cadomella Moorei (Davidson)	*communis*-zone (Smithe).
Koninckella liasina (Bouchard)	do.
Lingula cf. *Beani*, Phillips ..	Marlstone [*spinati*], Stanway Hill.
—— *Davidsoni*, Oppel ..	*oxynoti* (*fide* Oppel).
—— *metensis*, Terquem ..	*Valdani*. Shackel's Pike, Cheltenham.
Rhynchonella acuta (Sowerby)	*spinati*.
—— *amalthei* (Quenstedt)	do.
—— —— var.	*margaritati* (Smithe). See Davidson, "Monogr. British Oolitic and Liassic Brachiopoda," Suppl., pl. xxviii., fig. 21, and p. 201.
—— —— var.	*communis*-zone (Smithe). See *Ibid.*, fig. 20.
—— —— var.	*spinati*, Bredon and Alderton Hills.
—— *calcicosta*, Davidson	*marmoreæ*.
—— cf. *calcicosta*, (Quenstedt) ..	*planorbis*, Heath-Hill outlier.
—— aff. *calcicosta*, (Quenstedt) ..	*armati*, Folly-Lane Pit.
—— *cynica*, S. Buckman	[*Moorei*.] Gravel-pit, Overbury.
—— *Deffneri*, Oppel ..	*gmuendensis*.
—— *dumbletonensis*, Davidson ..	*spinati*. Type-specimen from Dumbleton Hill: See Davidson, "Monogr. British Oolitic and Liassic Brachiopoda," Suppl. pl. pl. xxix., fig. 5, and p. 199.
—— *fimbria* (Quenstedt)	*striati*. See "Handbuch der Petrefaktenkunde (1852), pl. xxxvi., figs. 14*a*, *b*, and p. 452. See **pl. xv., figs. 5*a*,** *b*, *c*, *d*, of present work.
—— cf. *fodinalis*, Tate ..	*capricornus*.
—— cf. *furcillata* (Von Buch) ..	*capricornus*.
—— *glevensis*, Smithe ..	*marmoreæ*. See "Monogr. British Oolitic and Liassic Brachiopoda," Suppl., pl. xxviii., fig. 22, and p. 221.
—— *media* (Sowerby) ..	*spinati*.
—— *oxynoti* (Quenstedt)	*oxynoti* and *varicostati*.
—— *plicatissima*, (Quenstedt) ..	*marmoreæ*.
—— *pygmæa* (Morris) ..	*communis*-zone. This little shell is not uncommon at Alderton Hill.

Rhynchonella radstockensis, Davidson ..	Middle Lias (*fide* Davidson).
—— *tetrahedra* (Sowerby)	*spinati*
—— sp.	*Valdani*. Always very much crushed.
Orbiculoidea Holdeni (Tate) ..	*Valdani*.
—— spp.	[*Moorei* ?] Gravel-pit, Overbury. See "Quart. Journ. Geol. Soc.," vol. lix. (1903), p. 447.
—— spp.	[*dispansi*.] Gravel-pit, Overbury. See *Ibid*., p. 447.
—— sp.	[*Lilli*.] Gravel-pit, Overbury.
—— sp.	*striati*. Attached to ammonites.
Spiriferina Hartmanni (Zieten)	[*spinati*.] Dumbleton Hill.
—— *ilminsterensis* (Davidson) ..	*communis*-zone (*fide* Smithe).
—— *Munsteri* (Davidson)	do.
—— *pinguis* (Zieten) ..	[*spinati*.] Dumbleton Hill.
—— *punctata* (J. Buckman).	*striati*. Figured "Geology of Cheltenham," 2 ed., pl. x., fig. 7, described p. 100.
—— *rostrata* (Schlotheim)	*spinati*.
—— *verrucosa* (Von Buch)	*armati*.
—— sp.	*Birchi*. Down Hatherley.
Terebratula Edwardsi, Davidson ..	*spinati*.
—— *globulina*, Davidson	[*Pre-falciferi* ?] Alderton and Churchdown Hills.
—— *punctata*, Sowerby ..	*spinati*.
—— *subpunctata*, Davidson	do.
—— *subovoides*, Roemer	*striati*. See **pl. xv., fig. 8.**
Terebratula ? *granulosa*, Davidson ..	*spinati* (Smithe).
Thecidella sp.	*spinati* (Smithe).
—— sp.	*marmoreæ*. Specimen on *Rhyn. calcicosta*, Davidson.
Zeilleria cornuta (Sowerby) ..	*spinati*.
—— *indentata* (Sowerby)	do.
—— *Mariæ* (d'Orbigny)	do.
—— aff. *perforata* (Piette)	*striati*.
—— *quadrifida* (Lamarck)	*spinati* (Smithe).

POLYZOA.

Berenicea sp.	*striati*.
—— sp.	*armati* (about).

CRUSTACEA.

MACROURA.

Eryma lævis, Blake	*spinati* (*fide* Smithe).

Eryma ?	[*Pre-falciferi ?*]
Glyphæa amalthei, Quenstedt	*spinati* (Smithe).
Pseudoglyphæa sp...	do.

Ostracoda.

Cythere spp.	The Rev. F. Smithe found ostracods "in no scanty number" in the upper portion of the deposit of *spinati* hemera at Churchdown Hill. See "Proc. Cotteswold Nat. F.C.," vol. vi., p. 364.
Cytherella spp.	*spinati*
Darwinula liassica (Brodie) ..	*Ostrea*-beds : *planorbis*.

INSECTA.

Orthoptera.

Heterophlebia Buckmani (Brodie)	Upper Lias [*pre-falciferi ?*].
Libellula Brodiei (J. Buckman)	do. See "Proc. Cotteswold Nat. F.C.," vol. i. (1853), p. 268.

Palæodictyoptera.

Mesoblattina Bensoni, Scudder	Upper Lias [*pre-falciferi ?*]
—— *Blakei*, Scudder ..	do.
Pterinoblattina Curtisi, Scudder	do.
—— *intermixta*, Scudder	do.

Rhynchota.

Belostomum sp.	*planorbis*.

Coleoptera.

Harpalus ?	*Ostrea*-beds.

ANNELIDA.

Ditrupa capitata (Phillips) ..	*spinati*.
—— *etalensis* (Piette) ..	*armati* (late).
—— aff. *etalensis* (Piette)	*spinati*.
—— *quinquesulcata* (Münster) ..	do.
Serpula limax, Goldfuss ..	do.
—— cf. *nodifera*, Terquem and Piette ..	*armati* (late).
—— aff. *plicatilis*, Goldfuss	*Valdani*.
—— *subpentagona*, Tate..	*oxynoti* to *armati*.
—— *tetragona*, Deslongchamps	*spinati*.
—— *tricristata*, Goldfuss	do.

ECHINODERMATA.

Crinoidea.

Extracrinus briareus (Miller) ..	*gmuendensis.*
—— *subangularis* (Miller)	*spinati* (*fide* Smithe).
Pentacrinus basaltiformis, Miller	*armati, oxynoti.*
—— *Goldfussi*, McCoy ..	*spinati.*
—— *gracilis*, Charlesworth	*Pre-falciferi ?*
—— *robustus*, Wright ..	*capricornus.*
—— *tuberculatus*, Miller ..	*marmoreæ* to *gmuendensis.*
—— *punctiferus*, Quenstedt ..	*oxynoti.*
Millericrinus Hausmanni (Roemer)	*spinati.*

Echinoidea.

Acrosalenia minuta (J. Buckman)	*oxynoti.*
Cidaris cf. *Edwardsi*, Wright	*Ostrea*-beds (*pre-planorbis*), and *planorbis.*
—— *amalthei*, Quenstedt	*spinati* (Smithe).
Hemipedina Etheridgii (Wright)	Marlstone, Bredon Hill. Figured "Proc. Cotteswold Nat. F.C.," vol. ii. (1860), pl. 1, fig. 5. and p. 22.
—— *Jardini*, Wright.	
Pseudodiadema lobatum, Wright.	
—— *Moorei* (Wright) ..	[*Pre-falciferi ?*] Figured "Proc. Cotteswold Nat. F.C.," vol. ii. (1860), pl. ii., fig. 3, and p. 27.
—— sp.	*Ostrea*-beds (*pre-planorbis*).

Ophiuroidea.

Acroura Brodiei, Wright ..	*capricornus.* Found by the Rev. P. B. Brodie during the excavation of the Battledown Reservoir, in association with *Pentacrinus robustus*, Wright. " . . . . the only specimen found." See Wright, "Monogr. British Fossil Echinodermata of the Oolitic Formations," Pal. Soc. (1864), p. 153, pl. xvii., fig. 5.

Ophioderma Gaveyi, Wright ..	*capricornus*. Fragments of the rays were found during the excavation of the Battledown Reservoir. See *Ibid.*, p. 147, pl. xv., figs. 1–3, pl. xvii., fig. 1.
Ophiolepis Ramsayi, Wright ..	"*angulata*-beds, Down Hatherley" (*fide* Brodie and Wright). *Ibid.*, p. 150, pl. xiv., fig. 3.

ACTINOZOA.

Isastræa sp.	Down Hatherley (*fide* Tomes).*
Montlivaltia Haimei, Chapuis and Dewalque	*rotiformis*.
—— *mucronata*, Duncan	[*armati ?*] Bredon (Tomes).
—— *rugosa*, Wright ..	*armati*.
—— *Ruperti*, Duncan ..	Down Hatherley (Tomes).*
—— sp.	*Valdani*.
Thecosmilia Martini, E. de Fromental	Down Hatherley (Tomes).*
Thecocyathus tuberculatus, Tomes	*communis*-zone (Tomes). Stanley (Langley) Hill. See "Geol. Mag.," dec. 3, vol. iii., pp. 107–111.
Trochocyathus sp.	*communis*-zone (Tomes).

FORAMINIFERA.

Cornuspira infima (Strickland)	*Spirillina*. "A few feet above the Insect-limestone of Wainlode Cliff" (Strickland). *Vide* "Memoirs of H. E. Strickland," p. 186.
Involutina liassica, Jones ..	*gmuendensis* (about.)
Polymorphina fusiformis, Roemer	*P. liassica*, Strickland. Same horizon as *C. infima*. Also Marlstone (Smithe).

* Apparently from the *angulata*-beds. The specimen of *Thecosmilia Martini* was found in association with the *Isastræa*, and "*Cardinia ovalis*, *Lima gigantea*, *Modiola*, *Astarte consobrina*, and many univalves." Concerning the stratigraphical position of *Montlivaltia Ruperti*, the Rev. P. B. Brodie wrote: "I found the last, *M. Ruperti*, when the new school was being built at Down Hatherley, near the Vicarage, really at a lower level than the spot where I found the *Thecosmilia* and *Isastræa*, and also in the brook below, still lower down as regards level, though stratigraphically higher owing to a slight dip of the beds and partial upthrow." "Quart. Journ. Geol. Soc.," vol. xxxiv. (1878), p. 186. During the excavation of the well for the pump in Down Hatherley, the present writer found *Arnioceras* sp., *Agassizoceras Sauzeanum*, *Spiriferina verrucosa*, var., *Rhynchonella* sp., *Pecten* spp., *Serpula*, *Lima* aff. *punctata*, and *Dentalium*: these from a deposit of the hemera *Birchi*.

PLANTÆ.

I.—Vascular Cryptogams.

(Pteridophyta.)

Equistales.

Equisetites Munsteri, Sternberg *planorbis*. Wainlode Cliff.

II.—Gymnospermæ.

Cycadophyta.

Otozamites sp. .. .. .. *planorbis*. Wainlode Cliff.

D.—List of Fossils from the Inferior Oolite.

REPTILIA.

Dinosauria.

Megalosaurus Bucklandi, Von Meyer	Lower Freestone. *Poikilopleuron.*

Crocodilia.

Steneosaurus megistorhynchus (Deslongchamps).	Gryphite-grit. *Vide* R. Lyddekker, "Catalogue of the Fossil Reptilia and Amphibia in the British Museum," part i. (1888), p. 116.

Ichthyopterygia.

(Ichthyosauria.)

Ichthyosaurus ?	Vertebræ and bones. Leckhampton and Sudeley Hills (Buckman and Strickland).

PISCES.

Elasmobranchii. (Selachii.)

Strophodus magnus, Agassiz ..	Lower Freestone.
—— sp.	Upper *Trigonia-* or *Clypeus*-grit.
—— sp.	Notgrove Freestone.

MOLLUSCA.

Cephalopoda.

Ammonoidea.*

Apedogyria platychora, S. Buckman	Oolite Marl.
Braunsina sp...	Lower *Trigonia*-grit.
Cosmogyria obtusa (Quenstedt)	Pea-grit.
Darellia polita, S. Buckman..	Lower *Trigonia*-grit.
Deltoceras subsectum, S. Buckman	do.
Emileia cf. *Brocchi* (Sowerby)	[*Phillipsiana-Bourguetia*-beds.]
—— cf. *Brocchi* (Sowerby)	*Witchellia*-grit.
—— cf. *grandis* (Quenstedt) ..	[*Phillipsiana-Bourguetia*-beds.]
Fontannesia cf. *tortiva*, S. Buckman	Lower *Trigonia*-grit.

* Compiled by S. S. Buckman, F.G.S.

Graphoceras sp.	Snowshill Clay.
Hammatoceras aff. *feuguerollense*, Brasil ..	*scissum*-beds, Cleeve and Nottingham Hills.
—— aff. *Newtoni*, S. Buckman ..	*scissum*-beds, Oxenton Hill (collected E. T. Paris).
Hyattia bullifera, S. Buckman	Type from the Pea-grit of the Cheltenham district (Birdlip ?).
—— *pustullifera*, S. Buckman ..	Pea-grit.
—— *Wilsoni*, S. Buckman	Pea-grit.
Hyattina Brasili, S. Buckman	do.
Hyperlioceras aff. *deflexum*, S. Buckman ..	Lower *Trigonia*-grit.
—— aff. *discites* (Waagen)	do.
—— aff. *discoideum* (Quenstedt) ..	do.
Kiliania spp. var.	Pea-grit.
Lioceras costosum (Quenstedt)	*scissum*-beds.
—— *gracile*, S. Buckman	do.
—— *plicatellum*, S. Buckman ..	do.
—— *Thompsoni*, S. Buckman ..	do.
—— *uncinatum*, S. Buckman ..	do.
Ludwigia Murchisonæ (Sowerby)	Pea-grit.
Ludwigia patula, S. Buckman	Oolite Marl, Charlton Common (collected E. T. Paris).
Lytoceras aff. *Eudesianum* (d'Orbigny)	Upper *Trigonia*-grit.
Manselia subfalcata, S. Buckman ..	Lower Freestone or Pea-grit.
—— *subacuta*, S. Buckman	Pea-grit.
Normannites cf. *Braikenridgii* (Sowerby)	[*Phillipsiana-Bourguetia*-beds.]
Oppelia subcostata (J. Buckman)	Upper *Trigonia*-grit.
Parkinsonia Parkinsoni (Sowerby)	do.
—— cf. *varicostata* (S. Buckman)..	do.
—— cf. *Schlœnbachi*, Schlippe	*Clypeus*-grit.
Reynesella sp.	Lower *Trigonia*-grit.
Reynesia cœla, S. Buckman ..	do.

laeviusculus Wilcdallen

Sonninia cf. *crassinuda*, S. Buckman ..	[*Buckmani*-grit.]
—— cf. *fissilobata* (Waagen)	Gryphite-grit, Leckhampton Hill.
—— *gracilobata* (Quenstedt)	*Witchellia*-grit, Cleeve Hill.
—— *ovalis* (Quenstedt) ..	? *Am. Greenhoughi*, "Geology of Cheltenham," 2 ed., p.28. Gryphite-grit.
—— cf. *Sowerbyi* (Miller)	*Witchellia*-grit, Cold Comfort.
—— *Stephani* (S. Buckman)	*Witchellia*-grit, Cleeve Hill.
—— *mesacanthus* (Waagen)	*Buckmani*-grit.
Sphæroceras sp.	*Phillipsiana-Bourguetia*-beds.
Strenoceras Garantianum (d'Orbigny)	[Upper *Trigonia*-grit], Leckhampton Hill.
Stepheoceras aff. *Baylianum* (Oppel)	*Bourguetia*-beds. *Vide* "Quart. Journ. Geol. Soc.," vol. liii. (1897), p. 609.
—— spp. var.	Lower *Trigonia*-grit.
Strophogyria cosmia, S. Buckman	Pea-grit.
Tmetoceras scissum (Benecke)	*scissum*-beds.
—— sp.	do.
Toxolioceras Walkeri, S. Buckman	Lower *Trigonia*-grit.
Welchia cf. *obtusiformis*, S. Buckman	Pea-grit.
Witchellia læviuscula (Sowerby)	*Witchellia*-grit.
—— cf. *Sutneri* (Branco)	do.
—— spp. var.	do.

BELEMNOIDEA.

Belemnites aff. *aalensis*, Voltz	Pea-grit.
—— *Blainvillii*, Voltz ..	*Bourguetia-Phillipsiana*-beds. *Belemnopsis*
—— *ellipticus*, Miller ..	do. *Megateuthis.*
—— *gingensis*, Oppel ..	Gryphite-grit. *Pachyteuthis.*
—— aff. *gingensis*, Oppel	Lower *Trigonia*-grit. *Pachyteuthis*
—— *insculptus*, Phillips ..	*Buckmani*-grit. *Pachyteuthis.*
—— *quinquesulcatus*, Blainville ..	*Bourguetia-Phillipsiana*-beds. *Megateuthis.*
—— aff. *spinatus*, Quenstedt ..	Snowshill Clay, Stanway Hill.
—— spp.	*Bourguetia-Phillipsiana*-beds.
—— sp.	*Buckmani*-grit.
—— spp.	*scissum*-beds.
—— sp.	Oolite Marl, Leckhampton Hill.

NAUTILOIDEA.

Nautilus clausus, d'Orbigny ..	Oolite Marl.
—— aff. *inornatus*, d'Orbigny ..	Pea-grit.
—— *latidorsatus*, d'Orbigny	Pea-grit, Crickley Hill.
—— *lineatus*, Sowerby ..	Lower *Trigonia*-grit.
—— cf. *lineolatus*, Foord and Crick	Base of Pea-grit, Kimsbury Castle, near Painswick.
—— cf. *ornatus*, Foord and Crick	*Phillipsiana-Bourguetia*-beds, Cleeve Hill.
—— *obesus*, Sowerby ..	Inferior Oolite, Leckhampton and Sudeley Hills (Buckman and Strickland).
—— *pseudolineatus*, Foord and Crick	Upper *Trigonia*-grit.
—— *truncatus*, Sowerby	Inferior Oolite, Leckhampton and Sudeley Hills (Buckman and Strickland).

GASTEROPODA.*

Actæonina (?) *convoluta*, Lycett	*Clypeus*-grit. Type-specimen in the Jermyn Street Museum.
—— *gigantea* (Deslongchamps)	*Parkinsoni*-zone [*Clypeus*- and Upper *Trigonia*-grits].
Alaria hamus (Deslongchamps)	*Parkinsoni*-zone [Probably Upper *Trigonia*-grit].
—— *Lorieri* var. *gracilis* (Lycett)	[Lower Freestone.]
—— *solida* (Lycett), var.	[Oolite Marl ?] Type-specimen at Jermyn Street.
—— *unicornis* (Lycett) ..	Oolite Marl. Very rare. Type-specimen at Jermyn Street.
Ataphrus Acmon (d'Orbigny)	Upper *Trigonia*-grit.
—— *heliciformis* (Morris and Lycett) ..	Oolite Marl and *Parkinsoni*-zone
—— *Labadyei* (d'Archiac)	*Clypeus*-grit.
Bourguetia striata (Sowerby)	*Bourguetia*-beds.
Cerithinella Brodiei, Hudleston	[Lower ?] Freestone.
Cerithium leckhamptonense, Hudleston ..	Lower Freestone, Leckhampton Hill. Type-specimen at Jermyn Street.

* This list, which is mainly compiled from "A Monograph of the British Jurassic Gasteropoda," Pal. Soc. (1887-1896), has been checked by Mr. W. H. Hudleston, F.R.S., F.G.S.

Cerithium pisoliticum, Hudleston ..	Pea-grit.
—— *vetustum* (Phillips) ..	*Parkinsoni*-zone.
Cirrus Calisto (d'Orbigny)* ..	Pea-grit.
Crossotoma cf. *Pratti*, Morris and Lycett	Pea-grit.
Cylindrites attenuatus, Lycett	Pea-grit, Leckhampton Hill. Type-specimen at Jermyn Street Museum.
Delphinula angulata, Hudleston ..	"Shell-bed [*scissum*-beds ?] below the Lower Limestone at Crickley." (Hudleston.)
—— (*Turbo*) *granata*, Bean MS., Hudleston ..	Inferior Oolite, Frith Quarry.
—— (*Margarita*) cf. *santonis*, Hudleston	[*Witchellia*-grit ?]
Emarginula granulata, Lycett	[Lower Freestone ?] Type-specimen at Jermyn Street.
—— *leckhamptonensis*, Lycett	Pea-grit. Type-specimen at Jermyn Street.
Exelissa strangulata (d'Archiac)	Pea-grit.
Fibula ? velox, Hudleston ..	[Oolite Marl ?]
Littorina dorsetensis, Hudleston ..	Pea-grit.
—— *Phillipsi* (Morris and Lycett)	do.
—— *pisolitica*, Hudleston	do.
Monodonta pisolitica, Hudleston	do.
Natica adducta, Phillips ..	Pea-grit and Oolite Marl.
—— *canaliculata* (Morris and Lycett) ..	[Pea-grit ?]
—— *cincta*, Phillips ..	Oolite Marl.
—— cf. *Lorieri*, d'Orbigny	[*Witchellia*-grit ?]
Nerinæa altivoluta, Witchell	Pea-grit. See "Proc. Cotteswold Nat. F.C.," vol. ix. (1890), p. 33.
—— *attenuata*, Witchell	Pea-grit and Oolite Marl.
—— *deducta*, Hudleston	Pea-grit.
—— *expansa*, Hudleston	Oolite Marl.
—— *Hudlestoniana*, Witchell	[Upper Freestone ?]
—— *oolitica*, Witchell ..	Oolite Marl.

* The gasteropod found somewhat abundantly in the Gryphite-grit at Leckhampton Hill, and presumably the cast of a much depressed *Pleurotomaria*, was named *Cirrus carinatus* by Sowerby.

Nerinæa pseudocylindrica d'Orbigny ..	Oolite Marl.
—— sp. (*pseudocingenda*,, Hudleston) ..	Lower Limestone.
—— (*Nerinella*) *conoidea* Hudleston ..	Oolite Marl.
—— —— *gracilis* (Lycett)	do.
—— (*Ptygmatis*) cf. *bacillus*, d'Orbigny	Upper Freestone.
—— —— *Guisei*, Witchell	*Clypeus*-grit.
—— —— *conica*, Witchell	Oolite Marl. Variety of *N.* (*P.*) *cotteswoldiæ*.
—— —— *cotteswoldiiæ*, Lycett ..	Oolite Marl and Pea-grit.
—— —— *Oppelensis*, Lycett ..	Oolite Marl.
—— —— *pisolitica*, Witchell ..	Pea-grit.
—— —— *stroudensis*, Witchell ..	[Upper Freestone ?]
—— —— *velox*, Witchell	Oolite Marl.
—— —— *xenos*, Hudleston	"Shell-bed below the Lower Limestone at Crickley."
Nerita costatula, Deshayes ..	Pea-grit.
—— *pseudocostata*, d'Orbigny ..	do.
—— (*Neridomus*) aff. *ovata*, Roemer	Oolite Marl.
Neritina sp. ("*subtransversa*," Hudleston)	do.
Neritopsis incisa, Hudleston ..	Pea-grit.
—— cf. *sulcosa* (d'Archiac)	do.
—— *varicosa*, Morris and Lycett	Inferior Oolite.
Patella (*Scurria*) *inornata*, Lycett ..	Lower Freestone.
—— —— *nitida*, Deslongchamps	[Lower Freestone ?]
—— *retifera*, Lycett ..	Lower Freestone.
—— *rugosa*, Sowerby ..	do.
Pileolus plicatus, G. B. Sowerby	Pea-grit.
Pleurotomaria angusta, Hudleston ..	Variety of *Pl. elongata*, Sowerby. Pea-grit.
—— *fasciata* (Sowerby) ..	[*Murchisonæ* ?]

Pleurotomaria ornata-depressa, Hudleston ..	do.
—— *platyspira*, d'Orbigny	*Murchisonæ* (that is from Lower Limestone to Lower Freestone inclusive).
Pseudomelania heterocycla (Deslongchamps)	Lower *Trigonia*-grit.
Puncturella cf. *acuta*, (Deslongchamps)	Pea-grit.
Purpurina elaborata (Lycett)	*Murchisonæ*.
Rimula alta, Lycett	[Lower Freestone ?]
—— *oolitica*, Hudleston ..	Lower Freestone.
—— *subtricarinata*, Hudleston ..	Pea-grit.
Rissoina gymnoides, Hudleston	do.
—— *obtusa*, Lycett	do.
Solarium diadema, Lycett ..	[Lower Freestone.]
—— *pisoliticum*, Hudleston ..	Pea-grit.
Trochotoma calix (Bean, MS., Phillips) ..	Oolite Marl.
Turbo (*Delphinula*) *Davousti*, d'Orbigny ..	*Parkinsoni*-zone.
—— *hamptonensis*, Morris and Lycett ..	" Different places and on different horizons in the Cotteswolds " (Hudleston).
Turritella (*Mathilda*) *abbas*, Hudleston	[Lower Freestone.]

LAMELLIBRANCHIATA.

(PELECYOPODA.)

Alectryonia aff. *flabelloides* (Lamarck)	*Phillipsiana-Bourguetia*-beds. = *Ostrea Marshi*, Sowerby.
Anatina pinguis, Agassiz ..	Oolite Marl (*fide* Lycett).
Arca æquata, Whidborne ..	Lower Freestone. See " Quart. Journ, Geol. Soc.," vol. xxxix. (1883), p. 520.
—— *Eudesi*, Morris and Lycett	Lower Freestone.
—— *lata*, Dunker	Lower Freestone.
—— *Pratti*, Morris and Lycett	Lower Freestone.
—— *pulchra*, Sowerby ..	Lower Freestone (Lycett). See " Mineral Conchology " (1824), pl. cccclxxiii., fig. 3.
—— sp.	Lower Freestone.

Astarte bullata, Lycett	Oolite Marl (Lycett).
—— *compressiuscula*, Morris and Lycett	do.
—— *depressa*, Goldfuss ..	do.
—— aff. *elegans*, Sowerby	Lower *Trigonia*-grit.
—— *excavata*, Sowerby ..	Lower *Trigonia*-grit; Oolite Marl (Lycett). *Cœlastarte*.
—— cf. *interlineata*, Lycett	Lower Freestone.
—— *orbicularis*, Sowerby	Lower *Trigonia*-grit.
—— *quadrata*, Lycett ..	Lower Freestone (Lycett).
—— aff. *rhomboidalis* (Phillips) ..	Lower *Trigonia*-grit.
—— *transversa*, Lycett ..	Oolite Marl (Lycett).
Avicula aff. *braamburiensis*, Sowerby	Upper *Trigonia*-grit.
—— *complicata*, J. Buckman ..	Pea-grit. See "Geology of Cheltenham," p. 97, pl. vi., fig. 5.
—— aff. *costata*, Sowerby	Pea-grit. See **pl. xviii., fig. 3.**
—— *digitata*, Deslongchamps	Upper *Trigonia*-grit.
—— cf. *echinata*, Sowerby	do.
—— sp.	*Phillipsiana-Bourguetia*-beds.
Cardium Buckmani, Lycett ..	Lower Freestone; Upper *Trigonia*-grit (Lycett). *Protocardium*.
—— *cognatum*, Phillips ..	Lower Freestone (Lycett).
—— *cordiforme*, Lycett ..	do.
—— cf. *incertum*, Phillips	Lower Freestone.
—— *semicostatum*, Lycett	Pea-grit; Lower Freestone (Lycett).
Ceromya bajociana, d'Orbigny	Lower *Trigonia*-grit.
—— *concentrica* (Sowerby)	Oolite Marl.
—— aff. *plicata*, Agassiz	*Clypeus*-grit.
—— *striata* (Sowerby) ..	Upper *Trigonia*-grit.
—— *undulata*, Morris and Lycett	*Clypeus*-grit.
Corbicella cf. *bathonica*, (Morris and Lycett)	Lower Freestone
—— *compressiuscula*, (Lycett)	"Gryphite-grit" (Lycett).
—— *ovalis* (Phillips) ..	
—— aff. *subæquilatera*, (Lycett)	Upper *Trigonia*-grit. See "Cotteswold Hills," p. 126.
—— *tumidula* (Lycett) ..	"Gryphite-grit" (Lycett).
Corbis aff. *aspera*, Lycett ..	Pea-grit.

Corbula imbricata, Lycett ..	Lower Freestone. See "Proc. Cotteswold Nat. F.C.," vol. i., p. 83.
—— *involuta*, Münster ..	= *C. striata*, J. Buckman; "Geology of Cheltenham," 2 ed., p. 97, pl. iii., fig. 4.
Cucullæa aff. *concinna*, Phillips	Upper *Trigonia*-grit.
—— *lævis* (J. Buckman)	Inferior Oolite [*Witchellia*-grit ?] Cold Comfort. See "Geology of Cheltenham," 2 ed., p. 97, pl. v., fig. 2.
—— *ornata* (J. Buckman)	do. *Ibid.*, p. 97, pl. v., fig. 1.
Cypricardia bathonica, d'Orbigny ..	*Murchisonæ*. "Prodrome de Paléont." (1850), p. 308.
—— *cordiformis*, Deshayes	Lower Freestone (Lycett).
—— cf. *rostrata* (Sowerby)	*Phillipsiana-Bourguetia*-beds.
—— sp.	Oolite Marl.
Cyprina curvirostra, Lycett ..	Oolite Marl.
—— *nuciformis*, Lycett ..	do.
—— sp.	do.
Cytherea picta, Lycett	Lower Freestone; Oolite Marl. See "Proc. Cotteswold Nat. F.C.," vol. i. (1853), p. 84.
Gervillia acuta, Sowerby ..	Lower *Trigonia*-grit.
—— *aurita*, Lycett ..	Oolite Marl; Lower Freestone. See "Proc. Cotteswold Nat. F.C., vol. i., p. 82, pl. ii., fig. 4.
—— *Hartmanni*, Goldfuss	Gryphite-grit.
—— *pernoides*, Deslongchamps	Upper *Trigonia*-grit.
—— *prælonga*, Lycett ..	Lower *Trigonia*-grit. See "Cotteswold Hills," p. 127, pl. vi., fig. 6.
—— aff. *subcylindrica*, Morris and Lycett	[Notgrove Freestone probably.]
—— *tortuosa* (Phillips) ..	[*Buckmani*-grit or Lower *Trigonia*-grit.]
—— aff. *tortuosa* (Phillips)	Oolite Marl.
Goniomya angulifera (Sowerby)	Oolite Marl.
—— v-*scripta* (Sowerby)	Lower *Trigonia*-grit.
—— sp.	Upper *Trigonia*-grit.
Gresslya abducta (Phillips) ..	Lower *Trigonia*-grit.
—— aff. *peregrina* (Phillips)	do.

Gryphæa "sublobata" (Deshayes)	Gryphite-grit: allied forms in the Lower *Trigonia-* and *Buckmani*-grits. See page 115 of present work.
Hinnites abjectus (Phillips) ..	Oolite Marl (Lycett); Pea-grit.
—— *sepultus*, Lycett ..	Lower Freestone (Lycett). See "Proc. Cotteswold Nat. F.C.," vol. i., p. 81.
—— *tuberculosus* (Goldfuss)	Pea-grit; Lower Freestone (Lycett).
—— *tumidus*, (Zieten) ..	Pea-grit. = H. *velatus* (Goldfuss),
Homomya gibbosa (Sowerby)..	*Clypeus*-grit; *Phillipsiana-Bourguetia*-beds.
—— aff. *crassiuscula*, Morris and Lycett	Gryphite-grit.
Isoarca capitalis, Whidborne	Lower *Trigonia*-grit.
Isocardia cordata, J. Buckman	*Buckmani*-grit. See "Geology of Cheltenham," 2 ed., p. 98, pl. vii., fig. 1.
Lima alticosta, Chapuis and Dewalque ..	Pea-grit.
—— *bellula*, Morris and Lycett	Upper *Trigonia*-grit. = *L. strigillata*, Laube.
—— aff. *bellula*, Morris and Lycett	*Buckmani*-grit.
—— cf. *cardiformis* (Sowerby) ..	Pea-grit.
—— aff. *educta*, Whidborne	*Witchellia*-grit. See "Quart. Journ. Geol. Soc.," vol. xxxix. (1883), p. 506, pl. xvii., figs. 4, 4*a*.
—— *gibbosa*, Sowerby ..	*Clypeus*-grit.
—— *pectiniformis* (Schlotheim) ..	*Buckmani*-grit: Pea-grit. = *Lima proboscidea*, Sowerby: *Ctenostreon pectiniforme* (Schlotheim).
—— *pontonis*, Lycett ..	Oolite Marl.
—— *punctatilla*, Lycett.	do.
—— *rigida* (Sowerby) ..	*Murchisonæ*.
Limea aff. *duplicata* (Sowerby)	Upper *Trigonia*-grit. See "Proc. Cotteswold Nat. F.C.," vol. ii., p. 131. **Pl. xviii., fig. 4.**
Lithodomus attenuatus, Lycett	Lower Freestone (Lycett).
—— *inclusus* (Phillips) ..	"Bored-bed" of the Bajocian Denudation.

Lucina Orbigniana, d'Archiac	Oolite Marl (Lycett).
—— *Wrighti*, Oppel ..	Oolite Marl.
—— sp.	do.
—— sp.	*Clypeus*-grit.
Macrodon hirsonensis (d'Archiac)	Oolite Marl (Lycett).
Modiola cuneata, Sowerby ..	*Buckmani*-grit.
—— *explanata*, Morris ..	*Mytilus*. See "Mem. Geol. Surv., 'Geology of the Country around Cheltenham,'" (1857,) p. 103, pl. i., fig. 1.
—— *gibbosa*, Sowerby ..	*Clypeus*-grit.
—— *imbricata*, Sowerby	*Mytilus*. Pea-grit.
—— *Sowerbyana* (d'Orbigny) ..	Lower *Trigonia*-grit. See **pl. xviii., fig. 6.**
—— aff. *Sowerbyana* (d'Orbigny) ..	*Buckmani*-grit.
Myacites compressiusculus, Lycett	Lower *Trigonia*-grit. See "Cotteswold Hills" (1857), p. 129, pl. v., fig. 1.
—— *compressus*, Lycett ..	Oolite Marl.
—— *dilata* (Phillips) ..	Oolite Marl = *Sanguinolaria dilata*, Buckman and Strickland; "Geology of Cheltenham," 2 ed., pl. vi., fig. 1.
—— *decurtatus* (Phillips)	Gryphite-grit.
—— *oblonga* (J. Buckman)	Lower Freestone (Lycett). "Geology of Cheltenham," 2 ed., pl. vi., figs. *2a*, *b*.
—— *punctatus* (J. Buckman) ..	Lower Freestone (Lycett). See "Geology of Cheltenham," 2 ed., p. 100.
—— *securiformis* (Phillips)	Gryphite-grit.
—— sp.	Upper *Trigonia*-grit.
Myoconcha crassa, Sowerby ..	Lower Freestone (Lycett): Gryphite-grit (Lycett).
—— *elongata*, Morris and Lycett	Oolite Marl.
—— *striatula* (Goldfuss) ..	Oolite Marl (Lycett).
Opis cordiformis, Lycett ..	Lower *Trigonia*-grit. "Cotteswold Hills," p. 128, pl. iv., figs. 2, *2a*.
—— *Deshayesi*, Lycett ..	*Clypeus*-grit.

Opis elongatus, Lycett	Oolite Marl and Lower Freestone.
—— *gibbosus*, Lycett ..	do. See "Proc. Cotteswold Nat. F.C.," vol. i., p. 82.
—— *similis* (Sowerby) ..	Upper *Trigonia*-grit.
Ostrea montiformis, Whidborne	Oolite Marl. = *O. gregaria*, Sowerby, of Inferior Oolite.
—— cf. *acuminata* Sowerby	Upper *Trigonia*- and *Clypeus*-grits.
—— *rugosa*, Goldfuss ..	Oolite Marl. = *O. costata*, Sowerby, of Inferior Oolite.
Pecten arcuatus, Sowerby ..	*Clypeus*-grit.
—— *articulatus*, Schlotheim ..	Lower *Trigonia*-grit; Lower Freestone; Pea-grit.
—— aff. *clathratus*, Roemer	Pea-grit.
—— *comatus*, Münster ..	Pea-grit.
—— *demissus*, Phillips ..	*Clypeus*- and Upper *Trigonia*-grits.
—— cf. *personatus*, Goldfuss	Notgrove Freestone.
—— cf. *retiferus*, Morris and Lycett	*Clypeus*- or Upper *Trigonia*-grit.
—— *subcomatus* Münster	Oolite Marl.
Perna rugosa, Goldfuss	Upper *Trigonia*-grit (Lycett).
—— *quadrata*, Phillips ..	Lower Freestone (Lycett).
—— spp.	*Witchellia*-grit.
Pholadomya aff. *bellula*, Whidborne ..	Oolite Marl. See "Quart. Journ Geol. Soc.," vol. xxxix., p. 534, pl. xix., figs. 10, 10*a*.
—— *Dewalquei*, Lycett ..	*Clypeus*-grit.
—— *fidicula*, Sowerby ..	Lower *Trigonia*-grit.
—— *Heraulti*, Agassiz ..	*Clypeus*-grit.
—— aff. *Heraulti*, Agassiz	Pea-grit.
—— *media*, Agassiz ..	Lower *Trigonia*-grit.
Pinna cuneata, Phillips.. ..	Oolite Marl.
—— *hastata*, Lycett ..	Oolite Marl (Lycett).
Placunopsis jurensis (Roemer)	[Pea-grit.]
Plicatula fistulosa, Morris and Lycett ..	Gryphite-grit (Whidborne).
—— *complicata* (Lycett)..	Pea-grit.
—— sp.	Lower Freestone; Oolite Marl.
Pteroperna sp.	Lower Freestone.
Quenstedtia lævigata (Phillips)	Upper *Trigonia*-grit (Lycett).
Sphæra Madridi, d'Archiac ..	Lower Freestone. "Mem. Soc. Géol. France," tom. v., pl. xxv., fig. 7.

Tancredia axiniformis (Phillips)	Lower Freestone.
—— *donaciformis*, Lycett	Lower Freestone (Lycett).
Trichites nodosus, Lycett ..	Pea-grit. See "Ann. and Mag. Nat. Hist." (1850), p. 347, pl. x.
—— *undulatus*, Lycett ..	Lower *Trigonia*-grit. See "Proc. Cotteswold Nat. F.C.," vol. i., p. 46.
Trigonia angulata, Sowerby ..	Oolite Marl.
—— *costata*, Sowerby ..	Upper *Trigonia*-grit
x —— *costatula*, Lycett ..	Oolite Marl. See "Proc. Cotteswold Nat. F.C.," vol. i., p. 253, pl. ix., fig. 5.
—— *duplicata*, Sowerby ..	Upper *Trigonia*-grit.
—— *formosa*, Lycett ..	*Buckmani*-grit.
—— *gemmata*, Lycett ..	Upper *Trigonia*-grit (very rare).
—— *hemisphærica*, Lycett	Lower *Trigonia*-grit (very rare).
—— aff. *pullus*, Sowerby	Oolite Marl; Lower Freestone Pea-grit.
—— *sculpta*, Lycett ..	Lower *Trigonia*- and Gryphite-grits.
—— *signata*, Agassiz ..	Upper *Trigonia*-grit.
—— aff. *striata*, Sowerby	Oolite Marl.
—— *subglobosa*, Morris and Lycett	do.
—— *tuberculosa*, Lycett ..	Lower Freestone.
Unicardium depressum (Phillips) ..	Upper *Trigonia*-grit.
—— *gibbosum*, Lycett ..	Oolite Marl.
—— *incertum* (Phillips) ..	*Clypeus*-grit.

Brachiopoda.*

Acanthothyris aff. *Crossi* (Walker)	*Buckmani*-grit.
—— cf. *paucispina*, S. Buckman .. and J. F. Walker	*Witchellia*-grit. + phillipsiana Bck.
—— *spinosa* (Schlotheim)	Upper *Trigonia*-grit. See **pl. xvii., fig. 2.**
—— cf. *tenuispina* (Waagen) ..	*Witchellia*-grit.
—— sp. nov.	*Buckmani*-grit. See "Quart. Journ. Geol. Soc.," vol. li. (1895), p. 447: also *Ibid.*, vol. lix. (1903), p. 384.
—— sp.	*Phillipsiana*-beds, Rolling Bank Quarry.
—— globosa (S.B.)	Buckmani grit ([illegible])

* In the preparation of this list the writer has received much assistance from Mr. S. S. Buckman, F.G.S.

Aulacothyris alveata (Quenstedt)	Pea-grit.
—— *Blakei* (Walker) ..	*scissum*-beds.
—— *carinata* (Lamarck)	Upper *Trigonia*-grit. Rare in this district.
—— *Meriani* (Oppel) ..	Lower *Trigonia*-grit. See **pl. xvi., figs. 4** *a* and *b*.
—— sp.	Lower Limestone, Cooper's Hill.
Crania spp.	Coral-bed on the top of the Pea-grit (collected C. Upton).
Pseudoglossothyris curvifrons (Oppel)	Oolite Marl. Common at Wistley Hill.
—— *galeiformis* (M'Coy)	Oolite Marl. Very rare.
—— *Leesi* (S. Buckman)	Lower Limestone (top).
—— *simplex* (J. Buckman)	Pea-grit: valve (ventral) from Lower Freestone, Cowley. Figured "Geology of Cheltenham," 2 ed., pl. vii., fig. 5, described p. 101. See **pl. xvi., fig. 5.**
—— nana (S. Buck)	Oo. Marl (Sol. Cuerv.)
—— aff. *simplex* (J. Buckman) ..	Elongate form. Top of Lower Limestone, Crickley Hill.
—— aff. *simplex* (J. Buckman) ..	Dwarf form in Oolite Marl. Rare.
Rhynchonella angulina, Davidson ..	Upper *Trigonia*-grit. = *Rhyn. angulata*.
—— auriculata Roll. Bas. Sol. & Scissum.	
—— *balinensis*, Szajnocha	Lower *Trigonia*-grit.
—— *Buckmani*, C. Upton, MS...	Pea-grit. A number of specimens have been obtained from Birdlip Hill. See footnote p. 77.
—— cottesvoldiae Upton. opalinum	
— clevensis Roll. -- L.T.G.	
—— *cynocephala* (Richard)	*scissum*-beds.
—— *cynomorpha*, S. Buckman ..	Upper Freestone. Figured "Quart. Journ. Geol. Soc.," vol. li. (1895), pl. xiv., figs. 2-4, described p. 452.
[illegible] Roll. : T.G.	
—— *granulata*, C. Upton, MS...	Oo. Marl (Sol. Cuerv.) / Pea-grit. See footnote p. 77.
—— *hampenensis*, S. Buckman ..	Upper *Trigonia*-grit. Figured "Proc. Cotteswold Nat. F.C.," vol. ix. (1890), pl. iii., fig. 6, described p. 42.
— cheltensis (Roll)	scissum (Sol. Cuerv.)

Rhynchonella Lycetti, Davidson.	Oolite Marl. Figured "Monogr. British Oolitic and Liassic Brachiopoda," pl. xv., fig. 6, described p. 81.
—— *oolitica*, Davidson ..	Pea-grit. Figured *Ibid.*, pl. xiv., fig. 7, described p. 81. Ob. Korl (5
—— aff. *oolitica*, Davidson	Oolite Marl. Rare.
—— cf. *parvula*, Deslongchamps	Oolite Marl.
—— *quadriplicata*, Davidson .. (non Zieten.)	*Phillipsiana*-beds.
—— *subangulata*, Davidson ..	Pea-grit.
—— aff. *subangulata*, Davidson ..	Pea-grit (top), Prinknash.
—— aff. *granulata*, C. Upton, MS... Ilsayensis Roll. ..	Oolite Marl. = *Rhyn. subangulata* of most authors- Clypeus Grit
—— *subdecorata*, Davidson: and varieties ..	*scissum*-beds.
—— *subobsoleta*, Davidson	Oolite Marl **See pl. xvii., fig. 3.**
—— aff. *subtetrahedra*, Davidson ..	Upper *Trigonia*-grit.
—— *Tatei*, Davidson ..	Upper Freestone.
—— *Wrighti*, Davidson ..	[*scissum*-beds or Pea-grit ?]
—— sp.	Probably of the *granulata*-type, but only the ventral valve is partially preserved. Harford Sands, Cleeve Hill.
—— sp.	*granulata*-type. "Dapple-bed."
—— sp. Brach Nom. Nuda .. .. Pl. 18 Fig 21.	*shiptonensis*, S. Buckman, MS., see p. 81. Pea-grit; Leckhampton and Crickley Hills, Frog-Mill railway-cutting, near Shipton. May be described as a dwarfed and
—— sp.	depressed form, allied to *Rhyn. subdecorata* (small).
—— sp. Mitchelli Roll.	Oolite Marl, (Charlton Common. ?) Very rare.
—— sp.	Lower *Trigonia*-grit.
Terebratula birdlipensis, Walker	*Clypeus*-grit.
—— *Buckmani*, Davidson	*Buckmani*-grit. See **pl. xvi., figs. 1** ***a***, ***b***.
—— *Buckmaniana*, Walker	*Phillipsiana*-beds.
—— cf. *cortenensis*, S. Buckman .. Cranhamensis	Lower *Trigonia*-grit (in *Meriani*-bed.) Buckmani-Grit

Terebratula crickleyensis, S. Buckman ..	*Buckmani*-grit. Figured in "Quart. Journ. Geol. Soc.," vol. li. (1895), pl. xiv., fig. 8, described p. 455. Type-specimen from Tuffley's Quarry. **Pl. xvi., figs. 6** *a*, *b*.
—— *Etheridgii*, Morris ..	See "Mem. Geol. Surv., 'The Geology of the Country around Cheltenham,'" pl. i., figs. 4 *a*, *b* and p. 103.
—— *euides*, S. Buckman	*scissum*-beds. *Vide* "Proc. Cotteswold Nat. F.C.," vol. xiii., pt. 2 (1889), pl. iii., figs. 8–10, and p. 126. Also "Geol. Mag.," dec. 3, vol. iii., p. 217.
—— *fimbria*, Sowerby ..	Oolite Marl. Varieties in Lower Freestone and Upper Freestone. Type-specimen from Charlton Common. See **pl. xvi., fig. 3.**
—— *Fleischeri*, Oppel ..	Upper *Trigonia*-grit. A *Terebratula* of the *globata*-group. Bathian spec see SSB. BN.B p 109
—— *globata*, Sowerby ..	Upper *Trigonia*- and *Clypeus*-grits. See **pl. xvi., fig. 2.**
—— *lentiformis*, C. Upton	Base of *Clypeus*-grit, Worden's Quarry; also Cleeve Hill. Figured "Proc. Cotteswold Nat. F.C.," vol. xiii., pt. 2 (1899), pl. iii., figs. 11–13, described p. 127.
microstoma Rol.	clypeus Grit.
—— *notgroviensis*, S. Buckman ..	Oolite Marl. Figured "Proc. Cotteswold Nat. F.C.," vol. ix. (1890), pl. iii., fig. 5, described p. 38.
painswickensis Rol.	Buckmani Grit
—— *permaxillata*, S. Buckman ..	*Clypeus*-grit. Described (but not figured) in "Proc. Cotteswold Nat. F.C.," vol. xiii., pt. 4 (1901), p. 261.
—— *Phillipsiana*, Walker	*Phillipsiana*-beds.
—— *pisolitica*, S. Buckman	Pea-grit. Figured "Proc. Cotteswold Nat. F.C., vol. ix. (1890), pl. iii., fig. 1, described p. 41. Type-specimen from Crickley Hill.

Terebratula plicata, J. Buckman	Pea-grit. Figured "Geology of Cheltenham," 2 ed., pl. vii., fig. 6, described p. 101. Type-specimen from Crickley Hill.
randwickensis Rll.	- - Pea Grit
—— *sphæroidalis* var., Davidson (non Sowerby)	Oolite Marl. The beak of this fossil must have been very weak, for in the specimens yet found it has been broken and a second foramen has been constructed. *Vide* "Monogr. British Oolitic and Liassic Brachiopoda," Suppl., pl. xviii., fig. 15.
—— *submaxillata*, Morris	Pea-grit. Allied forms in the Lower Freestone, Oolite Marl, Upper Freestone, Snowshill Clay, and *Witchellia*-grit. ✗
[illegible] Rll.	- L.T.G.
—— aff. *trilineata*, Young and Bird	Top of Lower Limestone.
—— *Uptoni*, S. Buckman	*Buckmani*-grit. Described (but not figured) in the "Quart. Journ. Geol. Soc.," vol. li. (1895), p. 455.
—— *ventricosa* ? Davidson (non Zieten) ..	Top of Lower Limestone, Crickley Hill. *Vide* "Monogr. British Oolitic and Liassic Brachiopoda," Suppl., pl. xv., figs. 10, 11.
—— *Wrighti*, Davidson ..	*Witchellia*-grit. Figured *Ibid.*, appendix vol. i., p. 20. See **pl. xvii, figs. 5** *a*, *b*.
—— *withingtonensis*, S. Buckman ..	Pea-grit. See **pl. xvi., figs. 7** *a*, *b*. Figured "Proc. Cotteswold Nat. F.C.," vol. xiii., pt. 4 (1901), pl. xii., figs. 8–12, described p. 246.
—— sp.	Top of Lower Limestone, Crickley Hill.
—— sp.	A form of *Ter. globata* ? very near to *Ter. sherbuirniensis*, S. Buckman. Upper *Trigonia*-grit, Tuffley's Quarry.
—— sp.	Top of Pea-grit.
—— sp.	Lower *Trigonia*-grit, Cleeve Hill. See p. 99.
——? Whitakeri	Ob. Marl (Geol. Chelt.)
rodborgensis. Rll.	clypeus Grit
witchelli. Rll.	U.T.G.
[illegible] dalis sp.	UTG

Zeilleria anisoclines, S. Buckman ..	*Phillipsiana*-beds. Type-specimen from the Rolling Bank Quarry. Figured "Proc. Cotteswold Nat. F.C.," vol. xiii., pt. 4 (1901), pl. xiii., fig. 10, described p. 258.
— cleevensis R.&U.	
—— *circularis,* S. Buckman ..	Pea-grit. Figured *Ibid.*, pl. xiii., fig. 9, described p. 257. Type-specimen from Crickley Hill.
—— aff. *circularis,* S. Buckman ..	Oolite Marl, Wistley Hill.
—— *Hughesi* (Walker) ..	Upper *Trigonia*-grit.
—— *Leckenbyi* (Walker)	Oolite Marl.
—— aff. *Leckenbyi* (Walker)	Top of the Pea-grit, Birdlip Hill.
— tenuis (Rich. + Upt.) Witchellia	
—— *Witchelli* (S. Buckman)	Oolite Marl. Figured "Proc. Cotteswold Nat. F.C.," vol. ix. (1890), pl. iii., fig. 4, described p. 39.
—— sp.	*Witchellia*-grit.
Thecidella triangularis (d'Orbigny) ..	*Phillipsiana*-beds.
—— *granulosa* (Moore) ..	Coral-bed on the top of the Pea-grit (C. Upton).
sp.	Attached to *Gryphææ* of Gryphite-grit (S. Buckman).
Waldheima. See *Zeilleria.*	

POLYZOA.*

Actinopora diplopora (Branco)	Oolite Marl, near Stroud ? ; Pea-grit, Crickley and Cleeve Hills ; top of Lower Limestone, Crickley Hill. See **pl. xviii., fig. 2.**
Apsendesia cristata, Lamouroux	Top of Lower Limestone, Crickley Hill ; Pea-grit, Crickley Hill.
Berenicea allaudi (Sauvage) ..	Lower Ragstone, Cold Comfort. "The specimen on which this record is founded is probably from the *Witchellia*-grit."—W. D. Lang.

* Or Bryozoa. This list has been drawn up by Mr. W. D. Lang, of the British Museum.

Berenicea archiaci, Haime ..	Pea-grit, Crickley Hill. See **pl. xviii., fig. 2^{1}**
—— *compressa* (Goldfuss)	Oolite Marl, Charlton Common; *Witchellia*-grit, Cold Comfort; Pea-grit, Crickley and Leckhampton Hills.
—— *coarctata*, Gregory ..	Inferior Oolite, Crickley Hill; Pea-grit, Leckhampton Hill.
—— *diluviana*, Lamouroux	*Clypeus*-grit, Cotteswolds.
—— *exilis*, Reuss	Pea-grit, Crickley and Cleeve Hills.
—— *spatiosa* (Walford) ..	Pea-grit, Crickley Hiill. See **pl. xviii., fig. 2^{2}**
—— *striata*, Haime	Inferior Oolite, near Leckhampton Hill.
—— *verrucosa* (M. Edwards)	Pea-grit, Cleeve Hill.
Ceriocava corymbosa (Lamouroux) ..	Inferior Oolite, Bredon Hill; Oolite Marl, Crickley and Ravensgate [Wistley?] Hills.
—— *laxata*, Gregory ..	Inferior Oolite, Leckhampton Hill.
Ceriopora arborescens, Waagen	Pea-grit, Crickley Hill.
Ceriopora globosa, Michelin ..	Pea-grit, Cleeve Hill; Oolite Marl, Ravensgate Hill [Wistley ?]. See **pl. xviii., fig. 1**, specimen from the *Witchellia*-grit, Cold Comfort.
Diastopora calloviensis (d'Orbigny) ..	Pea-grit, Brockhampton.
—— *Davidsoni*, Haime ..	Pea-grit, Cleeve Hill.
—— *foliacea*, Lamouroux	Pea-grit-equivalent, Bredon Hill.
—— *lamellosa*, Michelin ..	Pea-grit, Cleeve Hill.
—— *Lamourouxi*, M. Edwards ..	Coral-bed on the top of the Pea-grit, Crickley Hill.
—— *Michelini* (Blainville)	Inferior Oolite, Leckhampton Hill and Postlip.
Haplœcia irregularis, Gregory	Pea-grit, Cotteswolds.
—— *straminea* (Phillips)	Inferior Oolite, near Stroud.
Heteropora capilliformis (Michelin) ..	Pea-grit, Cotteswolds.
—— *conifera* (Lamouroux)	Oolite Marl; Pea-grit, Crickley Hill; gravel-pit, Charlton Kings.

Kololophos Terquemi (Haime)	Inferior Oolite, Birdlip; Pea-grit, near Cheltenham; *Clypeus*-grit, near Leckhampton.
Multiclausa Haimei, Gregory	Pea-grit, near Cheltenham.
Proboscina Eudesi, Haime ..	Pea-grit, Crickley Hill.
—— *Jacquoti*, Haime ..	Pea-grit, Crickley Hill.
—— *morinica* (Sauvage)	Pea-grit, Cleeve Hill.
Spiropora annulosa (Michelin)	*Witchellia*-grit, Cold Comfort; Lower *Trigonia*-grit, Wistley Hill; *Buckmani*-grit, Leckhampton Hill [see **pl. xix., fig. 3**]; Pea-grit-equivalent, Bredon Hiil. Bredon Hill.
Stomatopora dichotoma (Lamouroux) ..	Top of Lower Limestone, Crickley Hill.
—— *dichtomoides* (d'Orbigny) ..	Pea-grit, Crickley Hill.
—— *Waltoni*, Haime ..	Inferior Oolite, Crickley Hill.
Terebellaria ramosissima, Lamouroux	Inferior Oolite, Cleeve Hill.
Theonoa Bowerbanki, Haime..	Pea-grit, Crickley Hill.

CRUSTACEA.

Macroura.

Eryma elegans, Oppel	Pea-grit, Leckhampton. See **pl. xix., fig. 4** [mentioned as fig. 1 in text]. = *E. Guisei*, Wright.

Ostracoda.

Bairdia spp.	Coral-bed on top of Pea-grit, Frith Quarry. "I have found Ostracoda in abundance at the Frith Quarry" (C. Upton *in litt.*, March 29th, 1904).
Cythere spp.	
Cytherella spp.	

Annelida.

Galeolaria socialis (Goldfuss)..	*Buckmani*-grit: allied forms in the Lower *Trigonia*-grit, Upper Freestone, Oolite Marl, and Lower Freestone.
Serpula convoluta, Goldfuss ..	Inferior Oolite, Leckhampton (Buckman and Strickland).
—— *deplexa*, Bean	Pea-grit = *S. flaccida*, Goldfuss.

Serpula filiaria, Goldfuss ..	Inferior Oolite, Leckhampton (Buckman and Strickland).
—— *grandis*, Goldfuss ..	*Buckmani*-grit.
—— *lævigata*, Lycett ..	Lower Freestone. Described "Proc. Cotteswold Nat. F.C.," vol. i., p. 81.
—— *plicatilis*, Goldfuss ..	Upper *Trigonia*-grit.
—— *quadrilatera*, Goldfuss	Inferior Oolite, Leckhampton (Buckman and Strickland).
—— cf. *tetragona*, Sowerby	*scissum*-beds.
Vermilia sulcata (Sowerby) ..	*Clypeus*-grit; Upper *Trigonia*-grit.

ECHINODERMATA.

Crinoidea.

Millericrinus Pratti, Gray ..	[About Lower Limestone.] See **pl. xix., fig. 1**, of present work, and "Quart. Journ. Geol. Soc.," vol. xxxviii., pp. 29–38, pl. 1.
Pentacrinus Austeni, Wright	Pea-grit.
—— *Desori*, Wright ..	do.
—— *Lorioli*, Wright ..	do.
—— *Milleri*, Austen ..	do.

Echinoidea.*

Acrosalenia Lycetti, Wright ..	Pea-grit. Figured "Proc. Cotteswold Nat. F.C.," vol. i. (1853), pl. iv., fig. 2, and see p. 156.
—— *spinosa*, Agassiz ..	Pea-grit. = *A. radiata*, Forbes. See *Ibid* (1860), pl. v., fig. 3.
Cidaris Bouchardi, Wright ..	Pea-grit. Figured *Ibid.*, vol. ii., pl. i., fig. 2, and see p. 19.
—— *Fowleri*, Wright ..	Pea-grit. Figured *Ibid.*, vol. i., pl. iv., fig. 5, and see p. 139.
—— *Wrighti*, Desor ..	Pea-grit.
Clypeus Ploti, Klien	Clypeus-grit. = *C. sinuatus*, Parkinson. See **pl. xvii., fig. 1.**
—— *Michelini* (Wright) ..	[Lower Freestone.]
—— *Hugi*, Agassiz	Upper *Trigonia*-grit.
Diplocidaris Wrighti, Desor ..	Pea-grit. See "A Monograph of the British Fossil Echinodermata of the Oolitic Formations," Pal. Soc., pl. i., figs. 5 *a*, *b*.

* Compiled mainly from "A Monograph on the British Fossil Echinodermata, from the Oolitic Formations," Pal. Soc. (1858—1880).

Echinobrissus clunicularis (Llwyd)	*Clypeus*-grit.
Galeropygus agariciformis (Forbes)	Pea-grit.
Hemipedina Bakeri (Wright)	do. Figured "Proc. Cotteswold Nat. F.C.," vol. ii. (1860), pl. i., fig. 4, and see p. 29.
—— *Bonei*, Wright ..	Pea-grit.
—— *perforata* (Wright) ..	do.
—— *tetragramma*, Wright	do.
—— *Waterhousei*, Wright	do.
Holectypus depressus, Leske ..	*Clypeus*- and Upper *Trigonia*-grits.
—— *hemisphæricus* (Agassiz).	do.
Hypoclypus caudatus, Wright	[Lower *Trigonia*-grit ?]
—— *ovalis*, Wright.	do.
Magnotia Forbesi (Wright) ..	Base of *Clypeus*-grit, Worden's Quarry.
Pedina rotata, Wright	Upper *Trigonia*-grit. *Echinopsis*.
—— *Smithi*, Wright ..	Pea-grit and Oolite Marl.
Pseudodiadema depressum (Agassiz)	Pea-grit.
Polycyphus Deslongchampsi, Wright	Pea-grit. Figured "Proc. Cotteswold Nat. F.C.," vol. ii., pl. ii., fig. 4, and see p. 35.
—— *normannus*, Desor ..	Upper *Trigonia*-grit. = *P. nodulosus*, Goldfuss.
Pygaster conoideus, Wright ..	Pea-grit.
—— *semisulcatus* (Phillips)	do. See **pl. xvii. fig. 4.**
—— *macrostoma*, Wright	Upper *Trigonia*-grit.
Stomechinus germinans (Phillips)	Pea-grit. *S. perlatus* (Desmarest).
—— *intermedius* (Agassiz)	= *Echinus granularis*, Wright.

ASTEROIDEA.

Goniaster obtusus, Wright ..	Pea-grit (*fide* Wright).

HOLOTHUROIDEA.

Chirodota convexa ? Whidborne	Coral-bed on top of Pea-grit, Frith Quarry (collected by C. Upton).

ACTINOZOA.*

Adelastræa consobrina (Edwards and Haime).	Pea-grit.
—— *tenuistriata* (Tomes).	Pea-grit.
Anabacia complanata (Defranc)	Pea-grit (top);† Oolite Marl; Lower *Trigonia*-grit; *Clypeus*-grit. = *A. orbulites* (Lamouroux).
Chorisastræa gregaria (M'Coy)	Lower *Trigonia*-grit. *Thecosmilia*.
—— *rugosa*, Tomes ..	Pea-grit (top).
—— sp.	"Beds under the Pisolite at Crickley Hill" (Tomes).
Cosmoseris vermiculais (M'Coy)	Pea-grit (top). and Pea-grit (proper).
Cyathophyllia oolitica, Tomes	Pea-grit (top).
—— sp.	do.
Dimorpharæa Lycetti (Duncan)	Pea-grit (top); Oolite Marl. *Cyclolites*. *Dimorphastræa dubia*, Tomes (non Fromentel).
—— *pedunculata*, Tomes	Pea-grit (top).
—— *Fromenteli*, Tomes ..	Pea-grit (top). *Thamnastræa*.
—— sp.	do.
Donacosmilia Wrighti (Edwards and Haime) ..	Pea-grit (top); Oolite Marl. *Axosmilia*. = *Montlivaltia Holli*, Duncan.
Epismilia porpita (Tomes) ..	Lower *Trigonia*-grit.
—— sp.	Lower *Trigonia*-grit.
Goniocora concinna, Tomes ..	Pea-grit (top).
Heterastræa sp.	Coral-bed at the base of the *Clypeus*-grit, Worden's Quarry.
—— sp. nov.	Lower *Trigonia*-grit, Wistley Hill.
Isastræa limitata, Lamouroux	Lower *Trigonia*-grit, Wistley Hill.
—— *serialis*, Tomes (non Edwards and Haime)	Lower Limestone.‡

* This list is mainly compiled from the papers by Mr. R. F. Tomes, F.G.S., in the "Quart. Journ. Geol. Soc.," vol. xxxviii. (1882), pp. 409-450; "Geol. Mag.," dec. 3, vol. iii. (1886), pp. 385-398, and 443-452.

† Or the "Fourth Coral-bed." By "Pea-grit (proper)" is meant the Pisolite between the Fourth Coral-bed and the Lower Limestone.

‡ "Compact yellow stone under the pisolite at Crickley" (Tomes).

Isastræa tenuistriata (M'Coy)	Pea-grit (top); Lower *Trigonia*-grit; coral-bed at the base of the *Clypeus*-grit, Worden's Quarry.
—— depressa, Tomes ..	Pea-grit (top). *I. expansa*, Tomes.
—— sp.	Lower Limestone.
Latimæandra Flemingi, Edwards and Haime ..	Pea-grit (top).
—— *Davidsoni*, Edwards and Haime ..	do.
—— *tabulata*, Tomes ..	do.
—— *Haimei*, Tomes ..	Oolite Marl.
—— *concentrica*, Tomes ..	Pea-grit (top).
Leptophyllia Flouresti, E. de Fromentel	Oolite Marl.
Microsolena porosa, Lamouroux ..	Pea-grit (top).
—— *regularis*, Edwards and Haime ..	Lower *Trigonia*-grit.
—— sp.	Pea-grit (top).
Montlivaltia concinna, Tomes	Pea-grit (proper).
—— *cupuliformis*, Edwards and Haime ..	Lower Limestone.
—— *dilitata* (Michelin) ..	Pea-grit (top).
—— *lens*, Edwards and Haime	Lower Limestone.
—— *Morrisi*, Duncan ..	Pea-grit (top). *Caryophyllia.*
—— *painswicki*, Duncan	Pea-grit (top); Oolite Marl.
—— *Smithi*, Edwards and and Haime ..	Lower *Trigonia*-grit.
—— *tenuilamellosa*, Edwards and Haime	Pea-grit (top and proper).
—— *trochoides*, Edwards and Haime ..	Pea-grit (top).
—— *Wrighti*, Edwards and Haime	do.
—— sp.	Lower *Trigonia*-grit.
—— sp.	do.
—— sp.	Upper Freestone.
—— sp.	Lower *Trigonia*-grit.
—— sp.	Pea-grit (proper).
Oroseris contorta, Tomes ..	Pea-grit (top).
—— *gibbosa*, Tomes ..	Lower *Trigonia*-grit.
—— *incrustans*, Tomes ..	Oolite Marl.
—— *oolitica*, Tomes ..	Base of Lower Limestone.
Placophyllia gracilis, Tomes ..	Pea-grit (top).
Phyllogyra Etheridgii (Duncan)	Lower *Trigonia*-grit.

Phyllogyra sinuosa, Tomes ..	Lower *Trigonia*-grit; Oolite Marl.
Phylloseris rugosa, Tomes ..	Pea-grit (top).
—— *incrustata* (Michelin)	do.
Stephanocœnia dendroidea, Tomes	Oolite Marl.
—— *expansa*, Tomes ..	Pea-grit (top). Type-specimen from Cooper's Hill.
Thecoseris polymorpha, Tomes	Pea-grit (top). *Palæoseris*.
Thecosmilia ramosa, d'Orbigny	do.
Thamnastræa crickleyensis, Tomes	do. *Synastræa*.
—— *Defranciana* (Michelin)	do.
—— *Duncani*, Tomes ..	do.
—— *flabelliformis*, Tomes	do.
—— *fungiformis*, Edwards and Haime ..	Lower *Trigonia*-grit.
—— *heteromorpha*, Tomes	Oolite Marl. Found as yet only at Leckhampton Hill.
—— *Lyelli*, Edwards and Haime	Pea-grit (top); Oolite Marl.
—— *Manseli*, Duncan ..	Lower *Trigonia*-grit. *Synastræa*.
—— *mettensis*, Edwards and Haime ..	Pea-grit (top); Lower *Trigonia*-grit.
—— *Terquemi*, Edwards and Haime ..	Pea-grit (top).
—— *Walcotti*, Duncan ..	do.
—— *Wrighti*, Tomes ..	Lower *Trigonia*-grit; *Witchellia*-grit.
—— *expansa*, Tomes ..	Pea-grit (top). Type-specimen from Birdlip Hill.
Thamnosmilia sp.	Oolite Marl.

SPONGIDÆ.*

Blastinia costata (Goldfuss) ..	Oolite Marl.
Corynella punctata, Hinde ..	do.
Diaplectia auricula, Hinde ..	Pea-grit.
Lymnorella inclusa, Hinde ..	Pea-grit; *Trigonia*-grit. *Lymnorea*,.
—— *mamillosa* (Lamouroux) ..	Pea-grit; Oolite Marl.
—— *pygmæa* (Sollas) ..	Pea-grit.
—— *ramosa*, Hinde ..	do.
—— sp.	*scissum*-beds.
Peronidella tenuis, Hinde ..	Pea-grit. *Peronella*.

* Compiled mainly from "A Monograph of the British Fossil Sponges" by Dr. G. J. Hinde: part iii., "Sponges of Jurassic Strata." London, 1893. Palæontograph. Soc.

FORAMINIFERA.

Mr. C. Upton has obtained a large number of specimens from the coral-bed on the top of the Pea-grit at the Frith Quarry, but has not at present (April, 1904) identified the various forms.

PLANTÆ.

THALLOPHYTA ?

Girvanella pisolitica, Wethered	Pea-grit. Described "Geol. Mag.", dec. 3, vol. vi., p. 200.
—— *incrustans* var. *Lucii*, Wethered	Upper Freestone.
—— sp.	*Clypeus*-grit.

E.—Fossils from the Great Oolite Series.

REPTILIA.

Ichthyopterygia.

Ichthyosaurus ?	Sevenhampton Common, near Cheltenham. See "Geology of Cheltenham," 2 ed., p. 72.

PISCES.

Elasmobranchii.

Hybodus grossiconus, Agassiz	Stonesfield Slate, Sevenhampton Common.
Strophodus magnus, Agassiz ..	Bed 5 of section on page 163.

CEPHALOPODA.

Ammonoidea.

Perisphinctes gracilis (J. Buckman)	Stonesfield Slate. See "Geology of Cheltenham," 2 ed., pl. iii., fig. 7, described p. 104. A specimen was obtained by Mr. S. S. Buckman near Pegglesworth.

Belemnoidea.

Belemnites aripistillum, Llwyd	Stonesfield Slate. *Belemnopsis.* = *B. fusiformis*, Parkinson, and *B. Fleuriausus*, d'Orbigny. See "Geology of Cheltenham," 2 ed., pl. iii., fig. 9.
—— *bessinus*, d'Orbigny	*Belemnopsis.* = *B. canaliculatus*, Buckman. "Geology of Cheltenham," 2 ed., p. 71, pl. iii., fig. 8.

Nautiloidea.

Nautilus sp.	Cast. Bed 1 of section on page 163.
—— sp.	Dagham Stone (*fide* H. B. Woodward): see page 156.

MOLLUSCA.

Gasteropoda.

Natica alta, J. Buckman ..	Bed 1 of section on page 163. Described "Geology of Cheltenham," 2 ed., p. 101.
—— *Hulliana*, Lycett ..	Great Oolite, Pinswell, near Chedworth.

Nerinæa Dufrenoyi, d'Archiac	Bed 1 of section on page 163.
Pseudomelania lineata (Sowerby)	Bed 1 of section on page 163.
Ptygmatis striata (J. Buckman)	Bed 1 of section on page 163. Described "Geology of Cheltenham," p. 102, and figured pl. iii., fig. 1.
Purpuroidea glabra, Morris and Lycett	Dagham Stone (*fide* H. B. Woodward).

LAMELLIBRANCHIATA.

Astarte elegans, Sowerby ..	Clay-bed, or bed 1 of section on page 163 (Buckman and Strickland).
—— sp.	Clay-bed.
Avicula echinata, Sowerby ..	Briary Copse, near Birdlip.
—— *Munsteri*, Goldfuss ..	*Oxytoma*. Stonesfield Slate (Buckman and Strickland).
Ceromya cf. concentrica (Sowerby) ..	Bed 1 of section on page 163.
—— excentrica, Agassiz	Kemble Beds (H. B. Woodward).
—— aff. plicata, Agassiz	= *Cardita V. costata*, J. Buckman: "Geology of Cheltenham," 2 ed., p. 69.
Corbula involuta, Münster ..	= *Corbula striata*, J. Buckman. *Ibid.*, p. 69.
Cucullæa lævis (J. Buckman)	Clay-bed (J. Buckman).
Cypricardia nuculiformis (Roemer)	Bed 4 of section on page 171.
Cyprina islipensis, Morris and Lycett	Cast. Well-section, near Chedworth.
Exogyra auriformis, Goldfuss	Stonesfield Slate and Ragstone (Buckman and Strickland).
Gervillia acuta, Sowerby ..	= *G. lanceolata*, Goldfuss. Stonesfield Slate and Ragstone (Buckman and Strickland).
Homomya Vezelayi (Lajoye)	Kemble Beds.
Lima cardiformis (Sowerby) ..	Minchinhampton Beds.
—— *gibbosa*, Sowerby ..	Sevenhampton (Buckman and Strickland). Clay-bed.
—— *impressa*, Morris and Lycett	Great Oolite, near Calmsden.
Limea duplicata (Sowerby) ..	Stonesfield Slate (Buckman and Strickland).
Lithodomus inclusus (Phillips)	Clay-bed.

Lucina bellona, d'Orbigny ..	Great Oolite.
Modiola furcata (Goldfuss) ..	*Mytilus*. Hampen railway-cutting.
—— *gibbosa*, Sowerby ..	Sevenhampton (Buckman and Strickland).
—— *imbricata*, Sowerby	See page 167.
—— *tenuistriata* (Münster)	Clay-bed, Sevenhampton (Buckman and Strickland).
Nucula Menkei, Roemer ..	Bed 5 of section on page 163.
Ostrea acuminata, Sowerby, var.	Limestone-layers in clay-bed.
—— *costata*, Sowerby ..	Clay-bed.
—— *gregaria*, Sowerby ..	do.
—— *Sowerbyi*, Lycett ..	Great Oolite: Forest Marble.
Pecten annulatus, Sowerby ..	Clay-bed.
—— *vagans*, Sowerby ..	do.
—— sp.	Dagham Stone.
Pholadomya aff. *deltoidea* (Sowerby) ..	Bed 5 of section on page 163.
—— *lyrata* (Sowerby) ..	do.
Pinna ampla (Sowerby) ..	Clay-bed (Buckman and Strickland).
Plicatula sp.	Top of Stonesfield Slate.
Protocardium subtrigonum (Morris and Lycett) ..	Minchinhampton Beds.
Tancredia axiniformis (Phillips)	Stonesfield Slate.
Trigonia impressa, Sowerby ..	do. **See pl. xix., fig. 5**
—— *Painei*, Lycett ..	Base of Minchinhampton Beds.
—— aff. *pullus*, Sowerby	Bed 3 of section on page 158.

BRACHIOPODA.

Rhynchonella concinna (Sowerby)	Clay-bed chiefly.
Terebratula aff. *globata*, Sowerby	Top of Stonesfield Slate.
—— *maxillata*, Sowerby	Kemble Beds. A variety occurs in the basement-clays of the Forest Marble.

POLYZOA.

Berenicea cf. *verrucosa* (M. Edwards)	Clay-bed.

CRUSTACEA.

Remains of	See "Fossil Insects" (1845), p. 48. Clay-bed and Stonesfield Slate.

CIRRIPEDIA.

Pollicipes ooliticus, J. Buckman	Stonesfield Slate. See "Geology of Cheltenham," 2 ed., p. 95, pl. iii., fig. 7.

INSECTA.

COLEOPTERA.*

Blapsidium Studeri, Giebel ..	Stonesfield Slate.
Bruchus	do.
Coccinella Wittsi, Brodie ..	do.
Carabus ?	do.
Curculioides	do.
Melolontha	do.
Pimelia Zekeli, Giebel	do.
Prionus ooliticus, Brodie ..	do.

ANNELIDA.

Serpula aff. *obliquestriata*, Morris and Lycett	Clay-bed : often on the shells.
Vermilia quinquangularis (Goldfuss)	do.

ECHINODERMATA.

CRINOIDEA.

Pentacrinus aff. *jurensis*, Goldfuss	Very rare. Stonesfield Slate.

ECHINOIDEA.

Acrosalenia spinosa, Agassiz ..	Clay-bed.
Echinobrissus clunicularis (Llwyd)	do.
—— *Woodwardi* (Wright)	Great Oolite. Well-section, near Chedworth : see page 175.
Clypeus Mulleri, Wright ..	Clay-bed.
Polycyphus normannus, Desor	do.
Pseudodiadema Parkinsoni, Desor	do.

ASTEROIDEA.

Astropecten cotteswoldiæ (J. Buckman)	Stonesfield Slate. See "Geology of Cheltenham," 2 ed., pl. iii., fig. 5, and p. 94.

* See "Geology of Cheltenham," 2 ed., pl. iv. ; and "Fossil Insects" (1845) pl. vi., figs. 16—21.

ACTINOZOA.

Anabacia complanata (Defranc)	Clay-bed, Sevenhampton Common. = *Anabacia orbulites* (Lamouroux).
Astrocœnia sp.	Clay-bed, Sevenhampton Common.
Favia pedunculata, Tomes ..	Stonesfield Slate, Sevenhampton Common. See "Quart. Journ. Geol. Soc.," vol. xxxix., p. 183, pl. vii., figs. 16, 17.
Isastræa sp.	Rowell Gate.
Microsolena aff. *porosa*, Lamouroux	Base of Minchinhampton Beds.
Thamnastræa mammosa, Edwards and Haime ..	Top of Great Oolite: see page 173.

PLANTÆ.

I.—Pteridophyta.

Filicales.

Thinnfeldia speciosa, Ettingshausen	= *Salicites longifolius*, J. Buckman "Geology of Cheltenham," 2 ed., p. 68, pl. i., fig. 1.

Ginkgoales.

Baiera Phillipsi, Nathorst ..	= *Stricklandia acuminata*, J. Buckman: "Geology of Cheltenham," pl. ii., fig. 2, p. 94. Stonesfield Slate, Sevenhampton Common.
Ginko digitata (Brongniart) ..	= *Stricklandia acuminata*, J. Buckman: "The Geologist," vol. v., pl. xx., p. 395. Stonesfield Slate, Sevenhampton Common.

II.—Gymnospermæ.

Cycadophyta.

Carpolithes conicus, Lindley and Hutton	Stonesfield Slate, Sevenhampton Common. See "Geology of Cheltenham," 2 ed., pl. ii., figs. 5, 6. Sevenhampton Common.

Ctenis latifolia (Brongniart) .. = *Cycadites ?* "Geology of Cheltenham," 2 ed., pl. i., fig. 3, p. 67. Sevenhampton Common.

Podozamites stonesfieldensis, Seward .. .. = *Lilia lanceolata*, J. Buckman; *Naiadea ovata*, J. Buckman; and ? *Bensonia ovata*, J. Buckman: "Geology of Cheltenham," 2 ed., pl. ii., figs. 1, 3, pp. 93, 94. See "Catalogue of the Mesozoic Plants in the Department of Geology, British Museum, 'The Jurassic Floras,'" pt. ii. (1904), p. 121, and pl. iii., fig. 4; pl. xi., figs. 1, 2. Stonesfield Slate, Sevenhampton Common.

Sphenozamites Belli, Seward .. = ? *Naiadea obtusa*, J. Buckman: "Geology of Cheltenham," 2 ed., p. 93, pl. i., fig. 2. Stonesfield Slate, Sevenhampton Common.

CONIFERALES.

Thuites expansus, Sternberg .. = *Thuytes cupressiformis*, Sternberg; and *T. expansus*, Phillips. See the "Geology of Cheltenham," 2 ed., pl. i., fig. 6, and p. 67.

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* In the preparation of this list the writer has received great assistance from Mr. A. C. Seward, F.R.S.

APPENDIX III.

Explanation of Map.

The geological information given in the map which accompanies this work is based, for the most part, on the labours of the Officers of the Geological Survey, as recorded in Sheet 44 (western half). This must necessarily be so, because there has been no opportunity for the writer to undertake the arduous labour of systematically resurveying the district. But in the many years which have elapsed since the official map was issued, the geological structure of the neighbourhood is much better known: not only have new exposures, like those of wells and railways, shown that the old interpretation could not be sustained, but old exposures have received new interpretation in the light of increased knowledge. Therefore, the map which is given with this work shows in places where investigations have been most actively carried on, and for the many differences of detail from the official publication some explanation is necessary.

Keuper and Rhætic.—As the "Tea-green Marls" are now classed with the Upper Keuper Stage, the superficial extent of the Rhætic Series is less than that which was represented.

Rhætic and Lower Lias.—To the geographical limits of the Rhætic the writer has paid special attention in connection with his papers on these rocks,* and most of the boundary-lines now inserted have been specially resurveyed. On the Gray-Hill outlier, near Wainlode, the basement-limestones of the Lower Lias, containing *Pleuromya crowcombeia*, *Ostrea liassica*, and *Modiola minima*, have been found. This fact has been indicated on the map by representing a small outlier of Lower Lias. A mile or so to the west of Tewkesbury, between the hamlet at the Upper Lode and Forthampton, two outliers were shown. The limits of

* Proc. Cotteswold Nat. F.C., vol. xiv., pp. 127-174; and pp. 251-253.

the Liassic rocks constituting the eastern outlier were represented as being doubtful, and although it has not been found possible to define these boundary-lines more exactly on the present map, attention may be drawn to the fact that deposits of the hemera *marmoreæ*, and of earlier date also, are exposed to view in the area which was coloured Rhætic below the cottages overlooking the river, so that the Liassic area must evidently be greater than was depicted. Most probably, the fault which has affected the Upper Keuper Sandstone in the neighbourhood of Ripple has disturbed the beds near the Upper Lode also. From the Geological Survey Map it would appear that the tract of country between the Brockeridge-Common fault, and what may be called the Ripple fault, has been depressed : the higher beds in the Upper Keuper Stage on the east side of the line of fracture being brought into juxtaposition with beds laid down earlier in the same age. This would mean that at the Upper Lode the basement beds of the Lower Lias should be faulted against older strata—beds of earlier date. And such would appear to be the case, for while in the steep bank above the river are exposed Liassic strata, a hundred yards or so to the west, the outburst of springs and the general appearance of the ground warrant the conclusion that the Rhætic is present. Until more exposures are available, however, the distribution of the deposits as shown on the present map must be considered tentative.

At Tewkesbury, when an excavation was made in the main-road near the Fever Hospital, ammonites were obtained. The writer was shown a *Schlotheimia* (*angulata*-type), so that the Lias must be represented as having a greater geographical extent at this locality.

Lower and Middle Lias.—The Geological Survey have regarded as Middle Lias only the zones of *Amm. spinatus* and *margaritatus*, say, roughly, in this district the Marlstone " rock-bed " and underlying sandy deposit. All the clay below they have mapped as Lower Lias. Prof. Judd has written : " The restriction of the Middle

Lias in England to the stage δ of Quenstedt has been, to a great extent, determined by the fact that between the periods γ and δ a more or less considerable change evidently took place in the conditions of deposition of the beds; and consequently over large areas a marked change in mineral character is found to occur at this horizon, while no such change is found between the deposits of the stages β and γ."

"The limits between the clays of the Lias β and γ and that of the sands, sandy shales, and ferruginous limestone of δ can usually be conveniently represented in a map; while it is almost impossible to draw a line of boundary in the midst of a series of clays of almost uniform character like those composing the Lias and γ."* Mr. H. B. Woodward has observed that to take the parting of the Lower Lias from the Middle Lias between the zones of *Am. capricornus* and *Am. margaritatus* is "a course that on stratigraphical grounds is the most convenient, ... and it is one also that coincides most nearly with the original division made in the Lias by John Phillips."† The argument of stratigraphical convenience may be admitted. It applies to this district, but it is not of value over any wide area, and necessarily has not had weight with many authorities. A matter of stratigraphical convenience has compelled one to follow the Survey arrangement: that this book could be used in conjunction with the Survey Map, which again could be a basis for the present chart. There is an economic convenience too, locally: the line of springs is on the junction of the "Middle" and "Lower" Lias.

However, the "Middle" Lias which was delineated on the Survey Map did not accord altogether with their own definition. There are places where the *capricornu*-beds were included in the Middle Lias. Such would seem to be the case on the north side of Nottingham Hill, but here it must be stated that the boundary-line was marked as doubtful. Proceeding down the track leading to

* "Mem. Geol. Surv., 'The Geology of Rutland'" (1875), pp. 46, 47.
† "Mem. Geol. Surv., 'The Jurassic Rocks of Britain,'" vol. iii. (1893), p. 33.

Greenway Lane, near Gotherington, from the summit of Nottingham Hill, a section of the "rock-bed" of the Middle Lias may be studied with the subjacent micaceous sandy shales. The latter deposit, however, is not of great thickness; for one spring, which floods the road, and another which is in the fields a little to the west, indicates where the base of the deposit lies. On the west flank of Nottingham and Cleeve Hills too great a thickness of the Middle Lias was represented; for Mr. S. S. Buckman informed the writer that wells sunk in connection with new houses by the side of the road leading up Cleeve Hill and well within what is mapped as Middle Lias, exposed thick blue clay—evidently the upper portion of what the Survey call Lower Lias. Such are cases that have been actually noted. It is probable that the lower limit of the "Middle" Lias would require revision on many of the steep hill-sides; because along this line the physical features on which the field-geologist depends so much are often entirely misleading—owing to landslips. The map would require to be checked everywhere by boring.

The Upper Lias and Inferior Oolite.—On the south side of Bredon Hill, the little valley half-a-mile to the north of Conderton was mapped as Inferior Oolite. Drainage excavations, however, showed clay here. There was no further evidence; but it was certainly Lias, and could hardly be anything else than Upper Lias. As such it is now represented.

From Andoversford, in the direction of Withington, far too much was mapped by the Survey as Upper Lias: far too little as Inferior Oolite. The cuttings on the new railway (Midland and South-Western Junction) have shown that conclusively. Mr. Buckman very kindly placed at the writer's disposal maps upon which he had drawn the boundary-line of the base of the Inferior Oolite Series in this area, and it is inserted in the present map on his authority.

"*Midford Sands.*"—There is necessarily much alteration here from what was mapped by the Survey, mainly due to the researches of Mr. S. S. Buckman. He has shown that the so-called "Midford Sands" of this district are strata of two different dates, separated by a considerable time interval.* The "Midford Sands" of Haresfield and Painswick are the Cotteswold Sands,† and are an arenaceous development of the Upper Lias:‡ they are argillaceous deposits at Bredon Hill, where they were mapped as Upper Lias.§ The "Midford Sands," however, from Crickley Hill eastward and north-eastward are, according to the same author, the *scissum*-beds of the Inferior Oolite.* I have been able to confirm this in many places: at Crickley and Birdlip Hills the *scissum*-beds rest directly on clay, and such is the case at Nottingham Hill. So the following alterations are necessary. The sands of the south-east part of the district remain much the same, but they are treated as local arenaceous Upper Lias—as g3, sandy development, not as g4. Then the sands of other parts of the map are almost bodily transferred to the Inferior Oolite, following the Survey lines, except where I have some evidence to the contrary. There may be northward of Crickley Hill some representative of Cotteswold Sands. In places there is some sand parting the *scissum*-beds from the Upper Lias clay. Fine yellow sand, with micaceous matter, is seen in the banks of the cutting through which the Cirencester Road passes half-a-mile north of the Seven Springs; but there is no good evidence as to the exact date of any sand in such position, and the amount is too thin to be mapped.

Forest Marble.—The well at Long Furlong shows that the Forest Marble has a greater extent than was depicted: the matter has been rectified in the present map.

The above are a few cases where alterations have been made either in regard to actual facts or from revision

* "Quart. Journ. Geol. Soc.," vol. lvii., p. 152.
† *Ibid.* Vol. lix., p. 457. § *Ibid.* Vol. xlv., p. 456. ‡ *Ibid.* Vol. lix., p. 447.
* "Quart. Journ. Geol. Soc.," vol. lvii. (1901), pp. 150, 151.

in the method of treatment. In other cases when departure is made from the Survey Map, it is done intentionally as the result of some information obtained.

Faults.—Several faults discovered since the publication of the Geological Survey Map are recorded: chiefly on the Cleeve Hill plateau.* The results of the Shurdington fault may be admirably studied between the Seven Springs and Upper Coberley. Standing by the quarry described on page 131, the student sees exposed therein the *Clypeus*- and (upper portion of the) Upper *Trigonia*-grits; in the same field, but on the opposite side of a depression, a small exposure of Fullers' Earth; while on the other side of the wall on the west is an old quarry in the Lower *Trigonia*-grit. The "throw" of the fault at this locality is sufficient to bring the Fullers' Earth at least into juxtaposition with the Lower *Trigonia*-grit, and most probably with earlier strata.

From the map it might be thought that the vale is remarkably free from faults, but when it is considered how dislocated are the rocks belonging to the Inferior and Great Oolite Series on the hills, and that the Liassic beds must have been affected by every movement subsequent to their formation, it will be understood that it is on account of the scarcity of sections, and the fact that in clay accumulations there are few distinctive lithic features for guidance, that it is so difficult to trace the lines of disturbance. Obviously a fault must run near the Rhætic section at Norton (see page 25) where the beds have an unusual dip of 28 degrees; and if sections were available the fracture known as the Shurdington fault would doubtless be seen to have affected to no small extent the clay-deposits of the vale.

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* "Quart. Journ. Geol. Soc.," vol. liii. (1897), p. 616.

PLATE XIV.

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PLATE XIV.

capricornus hemera.

Figs. 1*a*, *b*:—*Cypricardia intermedia*, Moore.
Clay-pit, Pilley, Leckhampton, Cheltenham.

capricornus hemera.

Figs. 2*a*, *b*.—*Macrodon intermedius* (Simpson).
Clay-pit, Pilley, Leckhampton, Cheltenham.

Valdani hemera.

Fig. 3.—*Cerithium ibex*, Tate. Twice natural size.
Clay-pit at Leckhampton Station, Cheltenham.

Estheria-bed, Upper Rhætic.

Figs. 4, 5.—*Estheria minuta* var. *Brodieana*, Jones.
Twice natural size.
Bourne Bank, near Defford, Worcestershire.

contorta Age. Lower Rhætic.

Fig. 6.—*Heterastræa rhætica*, Tomes.
Near Deerhurst, near Tewkesbury.

armati hemera.

Fig. 7.—*Dentalium elongatum*, Münster. Twice natural size.
Clay-pit, Folly Lane, Cheltenham.

contorta Age. Lower Rhætic.

Fig. 8.—*Pleurophorus angulatus*, Moore.
Lower *Pecten*-bed.
Coomb Hill, near Cheltenham.

Valdani hemera.

Fig. 9.—*Turbo admirandus*, Tate. Twice natural size.
Clay-pit at Leckhampton Station, Cheltenham.

spinati hemera. Marlstone.

Fig. 10.—*Paltopleuroceras pseudocostatum* (Hyatt).
(Identified by S. S. Buckman, F.G.S.)
Alderton Hill.

capricornus hemera.

Fig. 11.—*Avicula* (*Oxytoma*) *inæquivalvis* (Sowerby).
Clay-pit, Pilley, Leckhampton, Cheltenham.

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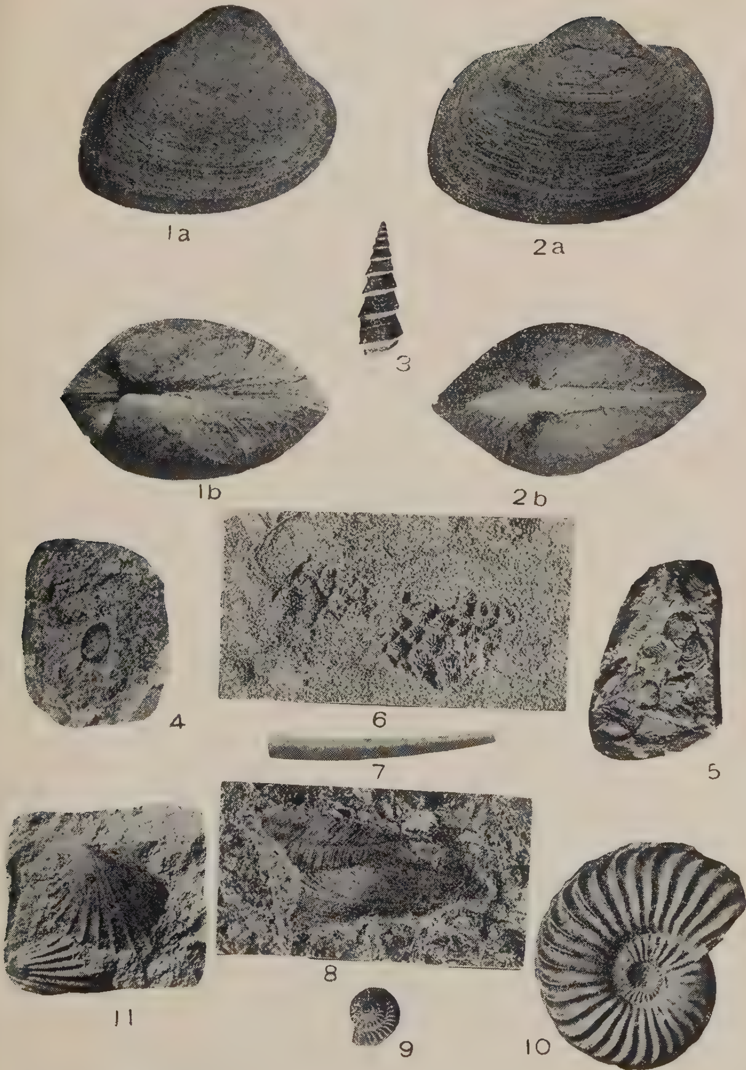
The above-mentioned specimens are in the writer's collection.

PLATE XIV.



FOSSILS FROM THE RHÆTIC AND LIAS OF THE CHELTENHAM DISTRICT.

(From Photographs by J. W. Tutcher.)

Plate XV.

Plate XV.

armati hemera (late).

Fig. 1.—*Turritella* sp. Twice natural size.
Clay-pit, Folly Lane, Cheltenham.

armati hemera (late).

Fig. 2.—*Dentalium* aff. *limatulum*, Tate. Twice natural size.
Clay-pit, Folly Lane, Cheltenham.

capricornus hemera.

Fig. 3.—*Cardinia* sp.
Clay-pit, Pilley, Leckhampton, Cheltenham.

striati hemera.

Fig. 4.—*Gervillia lævis*, J. Buckman.
Clay-pit (Webb's), Battledown, Cheltenham.

striati hemera.

Figs. 5*a*, *b*, *c*, *d*.—*Rhynchonella fimbria* (Quenstedt).
Clay-pit (Webb's), Battledown, Cheltenham.

striati hemera.

Fig. 6.—*Modiola* aff. *scalprum*, Sowerby.
Clay-pit (Webb's), Battledown, Cheltenham.

capricornus hemera.

Fig. 7.—*Liparoceras capricornu* (Schlotheim).
Clay-pit, Pilley, Leckhampton, Cheltenham.

striati hemera.

Fig. 8.—*Terebratula subovoides*, Roemer.
Clay-pit (Webb's), Battledown, Cheltenham.

Fig. 9.—*Macrodon Buckmani* (G. F. Richardson).
Clay-pit (Webb's), Battledown, Cheltenham.

striati hemera.

Fig. 10.—*Cardinia attenuata* (Stutchbury).
Clay-pit (Webb's), Battledown, Cheltenham.

capricornus hemera.

Fig. 11.—*Nuculana graphica* (Tate).
Clay-pit, Pilley, Leckhampton, Cheltenham.

The above-mentioned fossils are in the writer's collection.

PLATE XV.

FOSSILS FROM THE LIAS OF THE CHELTENHAM DISTRICT.

(From Photographs by J. W. Tutcher.)

Plate XVI.

Plate XVI.

Post-discitæ.

Figs. 1*a*, *b*.—*Terebratula Buckmani*, Davidson.
Buckmani-grit.
Tuffley's Quarry, near the "Air Balloon," near Birdlip.

Truellii, or *zigzag* hemera.

Fig. 2.—*Terebratula globata*, Sowerby.
Clypeus-grit (see page 89).
Quarry half-a-mile south-east by east of the Seven Springs, Cheltenham.

bradfordensis hemera.

Fig. 3.—*Terebratula fimbria*, Sowerby.
Oolite Marl.
Leckhampton Hill, Cheltenham.

discitæ hemera.

Figs. 4*a*, *b*.—*Aulacothyris Meriani* (Oppel).
Lower *Trigonia*-grit.
Charlton Common, Cheltenham.

Murchisonæ hemera.

Fig. 5.—*Pseudoglossothyris simplex* (J. Buckman).
Pea-grit.
Crickley Hill, near Cheltenham.

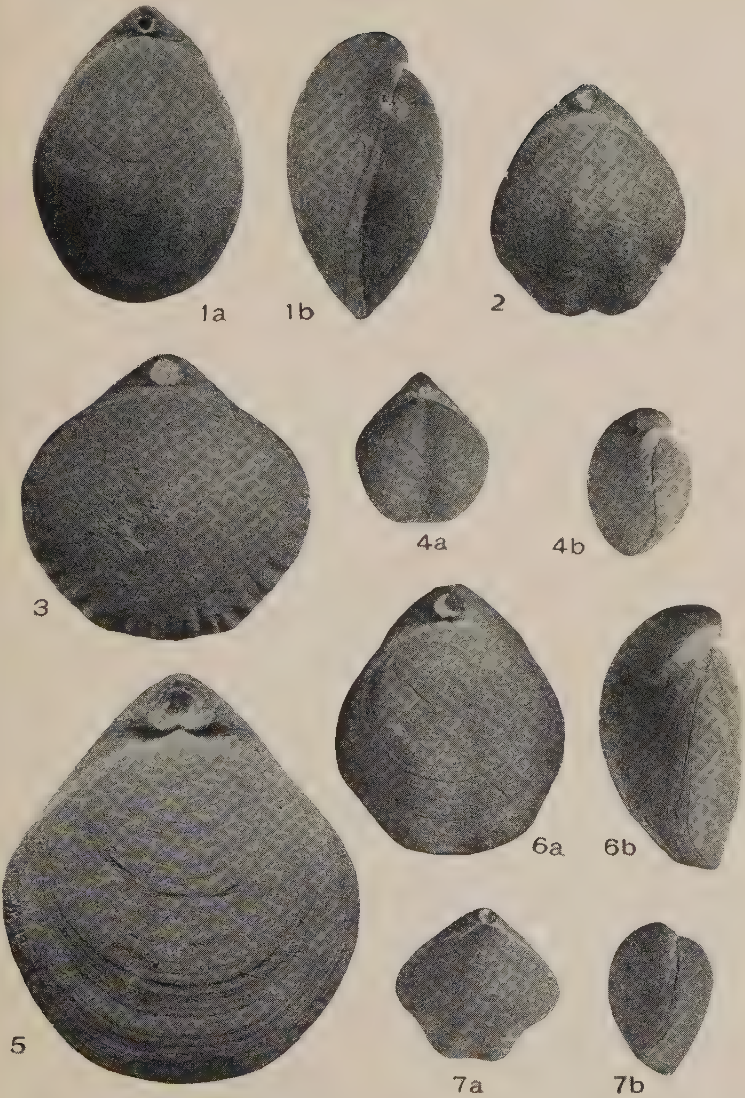
Post-discitæ.

Figs. 6*a*, *b*.—*Terebratula crickleyensis*, S. Buckman.
Buckmani-grit.
Tuffley's Quarry, near the "Air Balloon," near Birdlip.

Murchisonæ hemera.

Figs. 7*a*, *b*.—*Terebratula withingtonensis*, S. Buckman.
Pea-grit.
Crickley Hill, near Cheltenham.

The above-mentioned fossils are in the writer's collection.



BRACHIOPODA FROM THE INFERIOR OOLITE OF THE CHELTENHAM DISTRICT.

(From Photographs by J. W. Tutcher.)

Plate XVII.

Plate XVII.

Truellii or *zigzag* hemera.

Fig. 1.—*Clypeus Ploti*, Klein.
Clypeus-grit.
Railway-cutting near Notgrove, near Cheltenham.

Garantianæ hemera.

Fig. 2.—*Acanthothyris spinosa* (Schlotheim).
Upper *Trigonia*-grit.
Quarry nine-tenths-of-a-mile south-west by west of Brimpsfield Church.

bradfordensis hemera.

Fig. 3.—*Rhynchonella subobsoleta*, Davidson.
Oolite Marl.
Charlton Common, near Cheltenham.

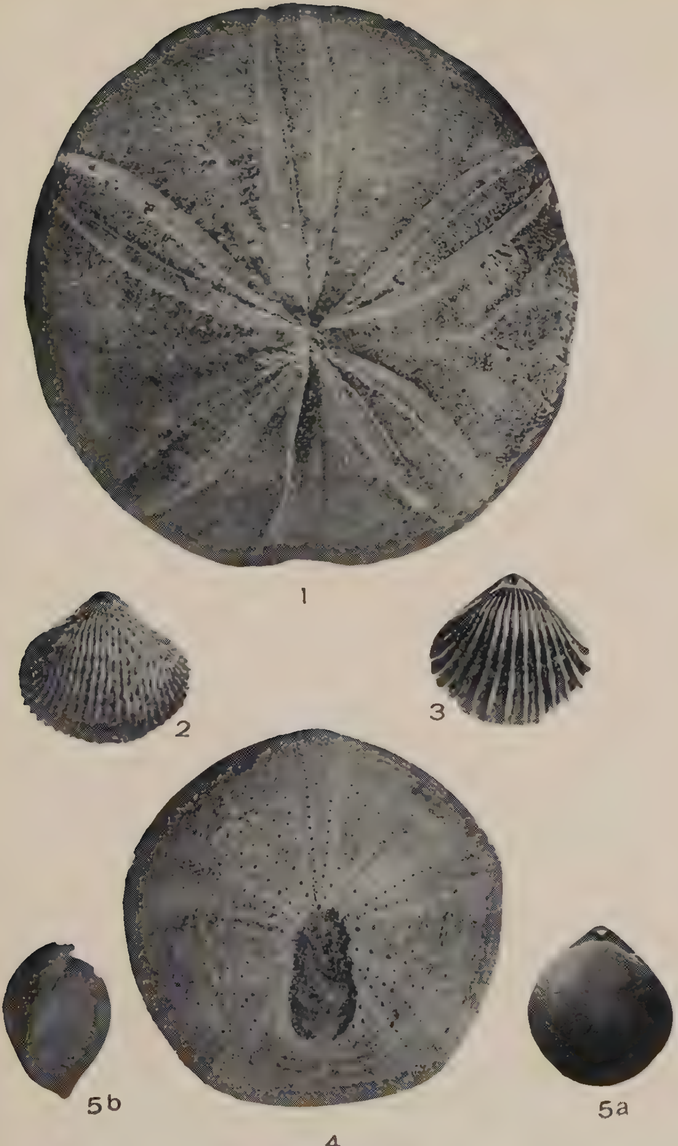
Murchisonæ hemera.

Fig. 4.—*Pygaster semisulcatus* (Phillips).
Pea-grit.
Crickley Hill, near Cheltenham.

Witchelliæ hemera.

Figs. 5*a*, *b*.—*Terebratula Wrighti*, Davidson.
Witchellia-grit.
Cold Comfort, near Cheltenham.

The above-mentioned fossils are in the writer's collection.



FOSSILS FROM THE INFERIOR OOLITE OF THE CHELTENHAM DISTRICT.

(From Photographs by J. W. Tutcher.)

Plate XVIII.

Plate XVIII.

Witchelliæ hemera.

Fig. 1.—*Ceriopora globosa,* Michelin.

Witchellia-grit.

Cold Comfort, near Cheltenham.

Murchisonæ hemera.

Fig. 2.—Fragment of shell with *Serpula;* 1 *Berenicea Archiaci,* Haime; 2 *Berenicea spatiosa* (Walford); 3 *Berenicea* resembling *verrucosa* (M. Edwards), but not that species, however; and 4 *Actinopora diplopora* (Branco).

Pea-grit.

Crickley Hill, near Cheltenham.

Murchisonæ hemera.

Fig. 3.—*Avicula* aff. *costata,* Sowerby.

Pea-grit.

Crickley Hill, near Cheltenham.

Garantianæ hemera.

Fig. 4.—*Limea* aff. *duplicata* (Sowerby).

Upper *Trigonia*-grit.

Quarry near Cowley Wood, near Cheltenham.

Fig. 5.—*Isastræa* sp.

[Said to come from Notgrove.]

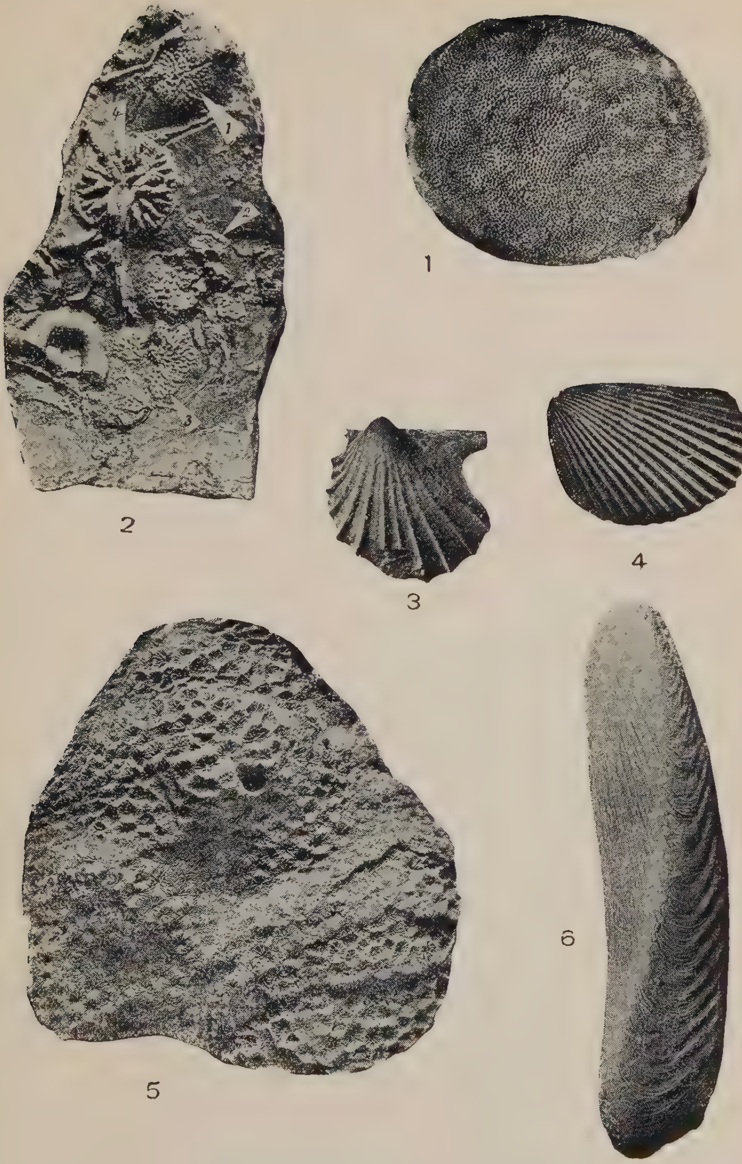
discitæ hemera.

Fig. 6.—*Modiola Sowerbyana* (d'Orbigny).

Lower *Trigonia*-grit.

"Roadstone Hole," Cleeve Hill, near Cheltenham.

The above-mentioned specimens are in the writer's collection.



FOSSILS FROM THE INFERIOR OOLITE OF THE CHELTENHAM DISTRICT.

(From Photographs by J. W. Tutcher)

Plate XIX.

Plate XIX.

Murchisonæ hemera.

Fig. 1.—*Millericrinus Pratti*, Gray. Slightly reduced.
[Lower Limestone.]
Andoversford, near Cheltenham.

striati hemera.

Figs. 2*a*, *b*.—*Arcomya elongata* (Roemer).
Clay-pit (Webb's), Battledown, Cheltenham.

Post-discitæ.

Fig. 3.—*Spiropora annulosa* (Michelin).
Buckmani-grit.
Leckhampton Hill, near Cheltenham.

Murchisonæ hemera.

Fig. 4.—*Eryma* sp.
Pea-grit.
"Firs-Brake" section (rubble capping), Leckhampton Hill, near Cheltenham.

subcontracti hemera.

Fig. 5.—*Trigonia impressa*, Sowerby.
Stonesfield Slate.
Quarry near Hawling, near Cheltenham.

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The above-mentioned fossils, with the exception of the *Millericrinus Pratti*, are in the writer's collection.

FOSSILS FROM THE CHELTENHAM DISTRICT

(From Photographs by J. W. Tutcher.)

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